ISSN 0829-9560

Evaluation of Health Status of Rocky Mountain Sheep in Southeastern British Columbia

by H.M.Schwantje
April 1988

BC Ministry of Environment

Wildlife Bulletin No. B-58

89-02345/

QC
WS
C
WS-B-63
1985
v.1

ISSN 0829-9560

Evaluation of Health Status of Rocky Mountain Sheep in Southeastern British Columbia

(*Ovis canadensis canadensis*)

- Project Report[1] -

H.M. Schwantje[2]

Wildlife Branch
Ministry of Environment
Victoria, B.C. V8V 1X4

Wildlife Bulletin No. B-58

April 1988

[1] Adapted from a thesis in partial fulfullment of the requirements for the degree of Master of Science in the Department of Veterinary Pathology, University of Saskatchewan, Saskatoon.

[2] Present address: R.R. #2, Normandy Road, Duncan, B.C. V9L 1N9

"Wildlife Bulletins frequently contain preliminary data, so conclusions based on these may be subject to change. Bulletins receive some review and may be cited in publications. Copies may be obtained, depending on supply, from the Wildlife Branch, Ministry of Environment, Parliament Buildings, Victoria, B.C. V8V 1X5."

Canadian Cataloguing in Publication Data

Schwantje, H. M.

Evaluation of health status of Rocky Mountain sheep in southeastern British Columbia (ovis canadensis canadensis)

(Wildlife bulletin, ISSN 0829-9560 ; no. B-58)

Bibliography: p.
ISBN 0-7726-0879-2

1. Bighorn sheep - Diseases - British Columbia - East Kootenay. I. British Columbia. Wildlife Branch. II. Title. III. Series: Wildlife bulletin (British Columbia. Wildlife Branch) ; no. B-58.

QL737.U53S38 1988 599.73'58 C89-092002-8

ABSTRACT

Three herds of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis* Shaw) in southeastern British Columbia were evaluated for health status during 1983 and 1984. Each herd was of similar size but varied in disease occurrence and herd dynamics, both historically and over the period of study. Samples taken from six sheep in each herd were examined for nutritional condition, microbiological, virological and serological status, general and pulmonary parasite loads, blood chemistry and trace mineral levels, as well as gross and histological lesions. The Columbia Lake herd at high animal density wintering on a poor quality, low elevation range was demonstrated to have high levels of lungworm infection, low total serum protein, fecal nitrogen and liver selenium levels. Higher total serum protein, fecal nitrogen, liver selenium levels and lower lungworm levels were present in bighorns from the lower density Ewin Ridge herd wintering at high elevation. Adrenal glands were larger, lungworm levels were lowest, and chronic clinical and subclinical systemic and respiratory diseases, were common in adults and lambs from a second herd (Wigwam) wintering at low elevation, 2 years after an all-age dieoff. Study herd status was best determined by comparison of fecal lungworm larval output, fecal nitrogen, liver selenium levels and pathological findings. Recommendations were made for future monitoring and management of bighorn herds. The Columbia Lake herd was treated with trace minerals and an anthelmintic after the 1983 collection. Lungworm larvae output was less in four sheep examined in the following year, but no change was seen in trace mineral levels.

TABLE OF CONTENTS

PAGE

ABSTRACT iii

LIST OF TABLES vi

LIST OF FIGURES vii

INTRODUCTION 1

STUDY HERDS 3

MATERIALS AND METHODS 6

RESULTS 9
- Clinical Evaluation and Condition 9
- Gross Necropsy 9
- Histopathology 11
- Laboratory Analyses 27

DISCUSSION 31

MANAGEMENT RECOMMENDATIONS 41
- Health Status Monitoring 41

LITERATURE CITED 45

APPENDIX 49

LIST OF TABLES

PAGE

TABLE 1. Selection criteria of bighorn sheep collected from three herds in the East Kootenays in 1983-84 13

TABLE 2. Body condition scores of bighorn sheep collected from three herds in the East Kootenays in 1983-84 14

TABLE 3. Preserved kidney:adrenal gland ratios of bighorn sheep from three herds in the East Kootenays in 1983-84 15

TABLE 4. Severity of histopathological changes in the tissues of bighorn sheep from the Columbia Lake, Wigwam and Ewin Ridge herds in southeastern British Columbia in 1983 ... 19

TABLE 5. Numbers of lungworm larvae per gram of feces and copper and selenium concentrations (wet weight basis) in liver of bighorn sheep collected from the East Kootenays in 1983-84 .. 29

TABLE 6. Serum fecal and urine chemistry values in bighorn sheep collected from the East Kootenays in 1983-84 30

LIST OF FIGURES

PAGE

FIGURE 1 Study area in southeastern British Columbia showing the location of study herds: Columbia Lake (CL), Wigwam (WW) and Ewin Ridge (ER) 4

FIGURE 2 Hepatic lesions including portal fibrosis, bile duct hyperplasia (arrows), mononuclear cell infiltration typical of that found in many sheep 17

FIGURE 3 Focal area of bronchopneumonia characterized by lobular consolidation, diffuse interstitial thickening, mononuclear peribronchiolar infiltrations and bronchiolar exudate 17

FIGURE 4 Small alveolar aggregates of neutrophils mixed with mucus and macrophages in bronchopneumonia caused by *Pasteurella haemolytica* 17

FIGURE 5 Fibromuscular hyperplasia of small airway in lung infected with *Protostrongylus stilesi* . Squamous metaplasia of away mucosal cells was common in these lungs 21

FIGURE 6 Chronic inflammatory response to various life stages of *Protostrongylus stilesi* 21

FIGURE 7 Diffuse infiltration of myocardium of sheep WW4 by large atypical lymphoid cells 21

FIGURE 8 Granulomatous foci in renal cortex of sheep WW5. Central mineralized areas are surrounded by giant cells, epithelioid cells, lymphocytes and plasma cells 21

FIGURE 9 Gram positive organisms (1 x 2 um) within renal tubular cells of sheep WW5 23

FIGURE 10 Same section under polarized light. The organisms are slightly birefringent 23

FIGURE 11 Ciliated protozoa within the pharyngeal submucosa of sheep from Ewin Ridge. The parasites were usually associated with focal epithelial and lymphoid cell necrosis 23

FIGURE 12 Ciliated protozoan within dilated abomasal gland of sheep ER4 23

INTRODUCTION

As has been described (Schwantje 1988), Rocky Mountain bighorn sheep undergo periodic all-age respiratory disease epizootics. The respiratory disease is characterized by a peracute to chronic bronchopneumonia. Opportunistic microorganisms are the most commonly identified pathogens, but immunosuppression by a complex of physiologic and environmental factors is believed to initiate clinical disease. Herds of bighorn sheep in the East Kootenay (E.K.) region of British Columbia have shown two basic patterns of herd dynamics; low elevation wintering herds that suffer periodic all-age dieoffs and high elevation wintering herds that remain stable in numbers.

Investigations into all-age dieoffs of bighorn sheep in the E.K. region of British Columbia in the 1960's and 1980's determined that these dieoffs were preceded by high population densities, heavy interspecies competition for forage, contact with domestic sheep, severe winter weather, high lungworm levels and low copper and selenium levels in some sheep (Stelfox 1971; Davidson 1982; Schwantje 1983). It was concluded that the herds in which dieoffs occurred were predisposed to pneumonia by chronic stress conditions caused and complicated by high animal density, poor nutrition, parasitism and trace mineral deficiencies. The presence of concurrent or subclinical diseases was unknown (Schwantje 1983).

Sheep herds wintering at high elevation were not affected during either of the previous dieoffs in the E.K. This suggested that the absence of some of the previously mentioned factors allowed the sheep herds at high elevation to be maintained in better overall health than those that suffer from dieoffs, and have thus avoided disease epizootics.

A definitive study was required to evaluate the presence of these factors in E.K. herds with and without the history of dieoffs. The following project surveyed three herds of similar size that differed in herd dynamics and disease occurrence. Samples were compared and evaluated for the presence and influence of predisposing factors, to describe the overall health of each herd and to apply this information to the overall management of E.K. bighorns.

The working hypotheses for this study were that:

1. Herds of bighorn sheep with differing histories of disease occurrence have differing, measurable physiological and pathological parameters.

2. Certain environmental and physiological factors can be associated with the differing parameters and these factors can be associated with the overall herd dynamics and health status.

3. Parameters can be selected and monitored to assist in the evaluation of herd status and appropriate management actions.

The study was designed to achieve the following major objectives:

1. To describe and compare the health status of individual bighorn sheep from three herds in the East Kootenay region of British Columbia.

2. To associate the health status of collected sheep with environmental and physiological factors and the overall dynamics of each herd.

3. To select parameters suitable for future monitoring of bighorn sheep herd health status.

This project was conceived, designed and carried out as a cooperative investigation involving numerous individuals and groups from the private, academic and government sectors, all sharing a special interest in that remarkable animal, the bighorn sheep.

Particular appreciation is expressed to the Foundation for North American Wild Sheep, the British Columbia Guide-Outfitters Association and the B.C. Ministry of Environment, Wildlife Branch for their financial support. The B.C. and Alberta Ministries of Agriculture, the Canadian Animal Disease Research Institute, W.M. Samuel, T.R. Spraker and A. Gajadhar generously donated analytical services. Invaluable field assistance and advice was provided by P.W. Davidson, R. Demarchi, T.R. Spraker, A. Wolterson-Strauss, C. Shepstone, D. Hebert and the hunters of the East Kootenays. Crownsnest Resources and G. Schuerholz permitted access to sheep range and their study data.

My special thanks for the enthusiasm and examples shown me by my supervisor G. Wobeser, and by D. Eastman and T.R. Spraker. Once again I also thank J. Brown, I. Shirley and L. Stevenson for their patience and persistence.

STUDY HERDS

The three herds selected for this project are designated by their winter range: Columbia Lake (CL), Wigwam (WW) and Ewin Ridge (ER) (Fig. 1).

The sheep from CL and WW herds graze summer pastures in lamb-ewe and juvenile and ram groups at elevations up to and above 2170 m. In the fall they return along what are believed to be traditional corridors to lower elevation (1000-1500 m), predominantly seral ranges along the eastern boundary of the Rocky Mountain Trench (Bandy 1968). The time of arrival on winter range varies between sexual groups and herds and may vary between years, but is usually during September and October (P. Davidson, pers. comm.). This is followed by the rut as breeding males arrive in November to December. The herds usually stay together on the winter ranges until early spring (April - May) when the pregnant ewes separate themselves and either stay or move to established lambing grounds in suitable terrain. The reverse migration occurs when snows retreat from the high country.

The winter ranges of these two herds are easily accessible by dirt road. They are heavily used during elk and deer hunting seasons, as well as for nonconsumptive recreational use, such as hiking and photography. Vehicle access to both winter ranges is possible until December 1 after which roads are closed. Although the closures are generally respected, vehicle and foot access is still possible and does occur after this date.

The CL range is situated at 50°12'N and 115°50'W. It consists of alluvial fans, parkland areas and rocky bluffs on the eastern shore of Columbia Lake. Conifer succession is very prominent around most meadows. Livestock have been absent from the range for over 20 years; however, mule deer and especially elk are abundant. The quality and amount of forage on this range has been considered poor since at least 1970 (Demarchi 1970; P. Davidson, pers. comm.). Enclosures erected in 1983 showed obvious differences in forage growth by 1984. The CL range is adjacent to a small community and shares a portion of the range with a growing residential subdivision. The sheep feed readily on planted grasses and wander through the subdivision to reach the lakeshore and mineral licks. Free-ranging dogs from the community are reported to frequent the winter range and cause considerable harassment to the sheep (P. Davidson, pers. comm.).

In 1966, a dieoff reduced the CL herd from 100 to 28 animals (Bandy 1968; Demarchi 1970). In 1983, the herd consisted of approximately 150 animals. Annual lamb:ewe ratios were considered to be gradually decreasing and were 0.4 to 0.5 in 1983 (P. Davidson, pers. comm.).

The WW range is made up of fire-formed alluvial plain grasslands, some natural parkland and thickly forested slopes between the Elk and Wigwam Rivers at 49°17'N and 115°5'W. Livestock are not permitted on the range but

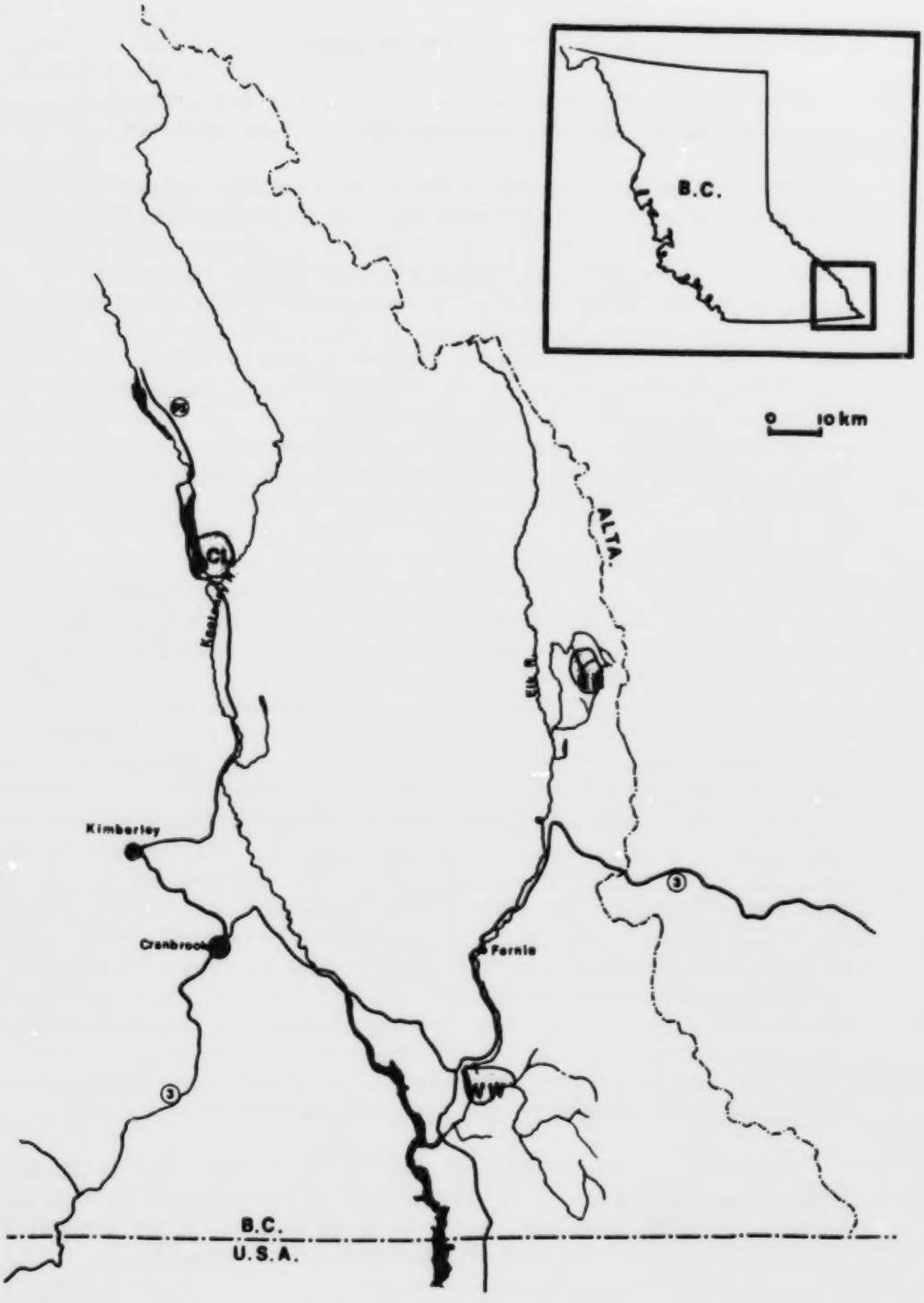


Fig. I. Study area in southeastern British Columbia

mule deer and, particularly, elk are abundant. The range condition appeared to have improved following reductions in the wildlife stocking rate, as was seen after a sheep dieoff in 1965 and subsequent increases in elk harvests (Demarchi 1970). It was considered to be improving after the 1981 sheep dieoff. The WW range is separated from a small community and a lumber mill by the Elk River. The inhabited shore is not often used by sheep. The side immediately opposite, however, has supported large groups of sheep in the past. Most of the available WW range is out of visual and acoustic contact with the community and mill.

The WW herd also suffered a 40-50% reduction in a major all-age dieoff in 1965 (Bandy 1968). The 150 animals remaining after the dieoff had increased to at least 424 by 1981, the highest density ever reported for the range (W. Warkentin, pers. comm.). At this time, elk and mule deer numbers were also considered high, similar to levels prior to the 1965 dieoff.

Another all-age dieoff began in December 1981 and reduced the population to fewer than 150 bighorns. Animals in poor condition and/or demonstrating respiratory symptoms were still occasionally reported in the years after the dieoff. The herd contained approximately 100-150 sheep with lamb:ewe ratios of less than 0.5 in 1983.

The ER sheep winter on virtually inaccessible, windswept, west-southwestern aspect subalpine and alpine ridges up to 2700 m in elevation at 50°4'N and 114°45'W. At this high elevation, both the rut and onset of winter conditions begin approximately one month earlier than on the low altitude ranges. Snow conditions closely control the movement of sheep so that they remain on winter range until a reduction of snowpack allows them to disperse. The amount of available range is reduced with heavy snowfalls or the late arrival of spring. When this occurs, intraspecific competition limits the quantity of forage available to overwintering sheep (Schuerholz 1983). A large open-pit coal mine is present on traditional ram summer range but the winter range common to both sexes is generally undisturbed. Extensive range studies demonstrated excellent range quality and a lack of forage or space competition from mule deer or elk (Schuerholz 1983, 1984).

This herd has never been reported to suffer large scale mortality, although, because of the location, we can only base our judgement on 15 years of aerial classified counts. These have remained stable at approximately 100-150 sheep since 1971 (Schuerholz 1984). The lamb:ewe ratio has averaged 0.55 since 1971 and was 0.78 in 1984.

MATERIALS AND METHODS

In 1983 and 1984, the CL and WW herds were observed by me and counted from the ground (foot and automobile). Data on the ER population were supplied by Crowsnest Resources and Transamerica Environmental Science Consultants (TAESCO), as well as through minimal direct observation during early winter. Animals in all herds were counted and differentiated as to sex and whether juvenile or adult (classified count) using fixed-wing aircraft or helicopter in January or February by British Columbia Wildlife Branch personnel.

Six sheep were collected from each herd. Selection criteria were designed to select for those animals of less than the average body condition, or that demonstrated clinical signs of disease, so that they appeared different from other sheep in the group. Criteria included body condition and clinical symptoms of disease or signs stated by wildlife biologists or experienced observers as indicative of poor condition or subclinical disease. The signs ranged from isolation behaviour in which an animal was isolated from the group, to pale or rough haircoats, loss of muscle mass, the presence of lesions of contagious ecthyma and mild to severe respiratory symptoms. Animals were also selected from three age classes: lambs of the year, yearlings and adult ewes. The collections from the ER herd used only the age class criteria.

From late October to early December 1983, observations of major CL and WW groups were made usually from a vehicle. The animals were observed for 0.5 to 1 hour before an individual was collected for sampling. Disturbance was considered minimal before collection. Ewin Ridge animals were observed from helicopter and collected after hazing towards a ground based hunter during late October and early November 1984.

Sheep were shot in the caudal skull or anterior cervical region. Blood was collected immediately, chilled and serum was harvested on the following day. Each animal was weighed and a necropsy was performed. Carcasses were evaluated subjectively for body condition on the basis of body fat deposits and muscling for a total body score of 100 after the method of Kistner (1980). Major organ systems were examined and representative portions were preserved in 10% neutral buffered formalin. The thoracic thymus was collected where identifiable, photographed and sectioned.

The lungs were removed intact and photographed. Lungworm affected lungs were classified as mild, moderate or severe. The mild classification had less than one-quarter of the caudal lobes affected by parasitic lesions, whereas moderate to severely affected sheep had one-third to one-half of the caudal lung lobes involved. Lesions of lungworm or bacterial pneumonia were recorded by drawing on a standard outline, and at least one 2 cm slice of each lobe was preserved. Portions of anterior or grossly affected lobes, as

well as a retropharyngeal lymph node and main stem bronchial swabs, were obtained for bacterial and viral culture. These tissues were chilled and frozen, respectively, and transported to the Alberta Agriculture Laboratory, Edmonton, Alberta for viral and bacterial culture using standard methods employed in that laboratory during the period October 1983 to December 1984 and under the direction of Dr. J.F.C.A. Pantekek.

Liver was frozen and assayed for trace minerals at the British Columbia Veterinary Pathology Laboratory, Abbotsford, using standard methods employed in that laboratory during 1985 and under the direction of R. Puls. The tissue was digested and analyzed by spectrophotometry for selenium levels and with atomic absorption spectrophotometry for copper, zinc and manganese. Copper and selenium levels were converted from parts per million to micromoles per litre by using conversion factors of 15.74 and 12.665, respectively.

Serum was frozen and analyzed later for antibodies to infectious bovine rhinotracheitis (IBR), parainfluenza 3 virus (PI3), bovine virus diarrhea (BVD) and bovine respiratory syncytial virus (RSV) by serum virus neutralization tests in cell culture at the Department of Veterinary Microbiology, Western College of Veterinary Medicine, Saskatoon, Saskatchewan, under the direction of Dr. P. Durham. The presence of antibodies to bovine lymphosarcoma virus (BLV) was determined for one animal from the WW herd by agar gel immunodiffusion at the Agriculture Canada Animal Disease Research Institute in Lethbridge, Alberta. Evaluations for antibody titres to bluetongue (BT), epizootic hemorrhagic disease (EHD), and Johne's disease (*Mycobacterium pseudotuberculosis*) were determined by agar gel immunodiffusion tests. Complement fixation was also used on sera for titres to Johne's disease. These tests were performed by standard methods used by the Agriculture Canada Animal Disease Research Institute, Nepean, Ontario, under the direction of Dr. J.O.L. Shapiro. Sera were evaluated by agar gel diffusion tests for maedi/visna virus antibodies using standard methods employed by Agriculture Canada in Sackville, New Brunswick, under the direction of Dr. R.G. Stevenson.

Samples of feces were frozen and analyzed for nitrogen by the Ministry of Agriculture Soil, Feed and Tissue Testing Laboratory, Kelowna, B.C. by a modified (Hebert *et al.* 1984) Kjeldahl method using selenium, hydrogen peroxide and sulphuric acid. Total fecal nitrogen content was then determined colourmetrically. Gastrointestinal parasite ova counts were done with routine fecal flotations and parasite identification was performed in the diagnostic laboratory, Department of Veterinary Microbiology, W.C.V.M. by A. Gajadhar. Fecal lungworm larvae counts were performed on air-dried feces by the Department of Zoology, University of Alberta, Edmonton, Alberta, using a Baermann technique (Samuel and Gray 1982).

Serum blood urea nitrogren levels were determined with a Beckman BUN Analyzer II (Brea, California) by an electrical conductivity method. Glucose levels were assessed with an ABA 100 (Abbott Diagnostics, Texas) using a hexokinase method. Total serum proteins were also assessed with an ABA 100 using a biuret reaction and an A-gent reagent (Abbott Diagnostics, Texas). These tests were performed by Clinical Pathology personnel, Department of Veterinary Pathology, W.C.V.M. Cortisol concentrations in serum and urine were determined by radioimmunoassay at the Department of Veterinary Pathology, College of Veterinary Medicine, Fort Collins, Colorado, using methods employed by that laboratory in 1985 and under the direction of Dr. T.R. Spraker.

Tissues for histology were embedded in paraffin, sectioned at 5 um thickness and stained with hematoxylin-eosin. Special stains (Masson's trichrome, PTAH, PAS, Grocott, Brown and Brenn) (Luna 1974) were used as required. Three microscopic sections were taken from each lung slice as well as additional sections from lesions seen grossly. The preserved left kidney and adrenal from each animal were weighed and photographed.

Histopathological findings were recorded for all organs. The microscopic changes in tissues other than the lung were graded into four categories on the basis of the severity of the most significant pathologic abnormalties. The significant abnormalties were inflammatory cell infiltration, lymphoid tissue hyperplasia and infection by *Sarcocystis* spp. and contagious ecthyma. Each was assessed subjectively and the degree of change ranked as normal, mild, moderate or severe.

Pulmonary disease was categorized on the basis of the most common microscopic changes. The prominent pulmonary changes were divided into seven major categories; those associated with the pleura and septae, airways, vessels, interstitium, alveoli, inflammation associated with lungworms and life cycle stages of *Protostrongylus* spp. Each of these categories was further subdivided to indicate either pathologic changes, the presence of specific inflammatory cells or parasite stages. Each lung section was examined without knowledge of the sheep of origin at 40 power magnification. Ten fields of view were surveyed following the same pattern and observing the presence or absence and severity of each change, cell type or parasite stage. These changes were summarized for each herd.

Statistical analysis was by one-way analysis of variance, where significance was detected, a Neuman-Keul's Range Test was used to differentiate among the groups. Means are reported with standard deviations, significance was accepted at $p \leq .05$.

RESULTS

CLINICAL EVALUATION AND CONDITION[1]

Columbia Lake

The sheep in the Columbia Lake herd were usually seen in groups of 40 to 65 animals. They could be approached to within 15 m and remained in the immediate area during all procedures. On clinical inspection individual sheep appeared in good to excellent body condition. The pelage was occasionally long and/or pale or yellow. Three sheep (CL 1, 4, 5) were selected for these haircoat changes (Table 1). One ewe was selected because of a mild dry cough (CL 6). This was the only sign noted during all observations. Some sheep had faintly depigmented areas on the oronasal mucosa, suggestive of healed contagious ecthyma lesions. A mean body condition score of 85.8 was estimated for collected sheep at necropsy (Table 2).

Wigwam

This herd was wary and was scattered as pairs or small groups over the range. Approach was possible by vehicle but sheep dispersed rapidly with disturbance. Field inspection revealed most of the sheep to be adults of poor to good body condition. Some groups were uniformly thin. Sheep selected had long pale haircoats and were thinner than average (Table 1). The two lambs collected (WW 1, 3) were very small, thin and lethargic. Both had nasal discharges and obvious oral lesions that appeared to be typical of contagious ecthyma. Oral contagious ecthyma was also severe in WW 4, mild in WW 5, with prominent nasal scarring in WW 6. Diarrhea with perineal staining was present in WW 3 and 5. All animals except WW 5 had *Otobius megnini* and *Dermacenter albipictus* ticks in light to heavy numbers. No signs of coughing were observed. The mean body condition score was 57.5 (Table 2).

Ewin Ridge

Clinical evaluation of these sheep was not possible but the carcasses were examined after collection (Table 1). The only noticeable abnormality was that the yearling (ER 4) had a pale but otherwise normal haircoat and was of small size. The other sheep were in good body condition with a mean body condition score of 80.8 (Table 2).

GROSS NECROPSY[1]

Columbia Lake

Five of the six CL sheep were classified as having moderate to severe verminous pneumonia. Animal CL 1 was classified to have mild lesions. All

[1] A complete description for individual animals is given in Appendix A.

pneumonic lesions were typical of those described by Spraker (1979) and others as resulting from infection by the lungworm *Protostrongylus stilesi*. Infected lungs had pale, firm, rounded nodules protruding from the surface of the lung. Nodules were always concentrated in the dorsal caudal lung lobes or the dorsal aspect of other lobes, but individual small nodules were occasionally present in distal cranial or middle lobes. Nodules were frequently fused in the caudal lobe and covered by thickened opaque pleura. Smaller nodules were translucent with yellow-grey mottling. Airways adjacent to lungworm nodules were usually surrounded by glistening white cuffs.

Protostrongylus rushi adults were present in the airways of all six sheep. A single small focus of consolidated parenchyma was present in the right cranial lung lobe in CL 6. This was later determined to be a sterile focus of bronchopneumonia, possibly induced by larval aspiration.

Wyominia tetoni tapeworms were found in four sheep (CL 2, 4, 5, 6). Heavy infections were accompanied by bile duct and gall bladder dilation and fibrosis. Sheep CL 4 had two 1- and 2- cm green laminated abcesses adjacent to these structures. Multiple 0.2-cm nodules on the abomasal rugae and tiny white foci over cecal and colonic serosae and mucosae were common and were considered to indicate gastrointestinal parasitism due to various nematode species, including *Ostertagia* and *Marshallagia* spp.. The kidney:adrenal weight ratios ranged from 24.6 to 37.3 with a mean of 30.4 (Table 3).

Wigwam

Mild lesions of verminous pneumonia were present in five sheep, with WW 5 classified as moderately affected. Opaque, white, individual nodules rather than diffuse swelling of caudal lobes were more common in these animals. Sheep WW 6 was the only animal in which *P. rushi* adults were identified.

Chronic bronchopneumonia and fibrous pleuritis were noted in four sheep (WW 1, 3, 4, 5). These ranged from a small area of consolidation of the cranial lobe in WW 5 to bilateral fibrous adhesions and areas of consolidation in the ventral portions of all lobes of WW 4. Consolidation was extensive in both lambs (WW 1 and 3) with sharp demarcation of affected ventral cranial and ventral middle and caudal lobes from the remainder of the lung. The firm, plum-coloured tissue had a cobblestone texture with scattered white foci and a mucoid exudate in the airways. Extensive fibrous pleuritis and pericarditis were also present in both lambs.

Gastrointestinal parasitism lesions were present in all WW sheep and were more severe in those with chronic pulmonary lesions. Sheep WW 4 and 5 had generalized enlargement of lymphoid organs, single white myocardial foci and multifocal pale renal streaking. Contagious ecthyma lesions were very severe throughout the oral cavity and rumen of WW 4 and mild in WW 5. The

lambs had thymic atrophy, serous atrophy of fat, lesions of contagious ecthyma and those associated with large numbers of gastrointestinal parasites. Lamb WW 3 was more seriously affected with fibrinous peritonitis, serous polyarthritis, decubitus ulcers and contagious ecthyma lesions of the coronet bands. The kidney:adrenal ratio ranged from 9.4 to 29.2, with a mean of 21.8 (Table 3). The lowest ratio, or largest adrenal size was in WW 3.

Ewin Ridge

Mild verminous pneumonia was diagnosed in three sheep (ER 1, 3, 4) and the remainder had mild-moderate (ER 5, 6) or moderate (ER 2) lesions. Nodules were mostly small and transparent. The most distal area of the caudal lobes was frequently contracted with pleural fibrosis. Two ewes (ER 5, 6) had small, contracted, consolidated areas in the middle lobes. *Protostrongylus rushi* adults were present within airways in ER 2 and 3.

Gastrointestinal parasitism lesions were restricted to the abomasum in ER 1, 2 and 4 and were moderate in number and severity. No depigmented areas or active contagious ecthyma lesions were present. Kidney:adrenal ratios varied from 26.1 to 34.2 with a mean of 28.0 (Table 3).

HISTOPATHOLOGY

The most consistent histological findings in all sheep from the three herds were lesions caused by hepatic and gastrointestinal cestode and nematode parasitism. The major hepatic changes were fibrosis, mononuclear cell infiltration and hyperplasia of bile ducts in portal regions, as well as small, cellular foci scattered throughout liver lobules (Figure 2). These small foci were often associated with portal areas but were also randomly distributed. The cell type was primarily mononuclear with occasional eosinophils and individual degenerating hepatocytes.

Abomasal inflammation consisted of nodular and diffuse mononuclear cell infiltrates. This lesion was less common in CL sheep. The small intestinal changes were diffuse mononuclear and eosinophilic infiltrations of the lamina propria. The more severely affected sections also had mucosal hyperplasia. Areas with superficial necrosis were associated with intracellular stages of coccidial organisms, subsequently identified as *Eimeria* spp., Lesions in the large intestine were less severe than those in the small intestine with less evidence of hyperplasia. Eosinophilic granulomas and focal chronic inflammation, suggestive of parasite migration, were occasionally present in the intestines, liver, lymph nodes and abomasum in sheep from all herds. The cardiac and skeletal muscles of sheep from WW and ER contained cysts of *Sarcocystis* spp.

Kidney changes primarily involved glomeruli or were interstitial with secondary glomerular and tubular effects. Glomerular basement membranes were

irregularly thickened and the mesangium was hypercellular. Severely affected glomeruli had adhesions and were shrunken. None of these lesions were considered to be extensive nor significant enough to cause clinical signs. The most severe kidney lesions were in two sheep from WW and were associated with a neoplasm in one sheep and granulomatous disease in another. Heart lesions noted grossly in these sheep were caused by the same generalized conditions.

Lymphoid tissue was hyperplastic in most animals. Severe systemic illness in a lamb from WW was accompanied by lymphoid atrophy. Systemic disease accompanied lymphadenopathy in two other sheep from WW. The epithelium overlying the pharyngeal lymphoid aggregates was altered in most sheep. These changes varied from hyperplasia and metaplasia to focal necrosis. The nasopharyngeal changes were generally mild or moderate and did not appear to have any relationship to other respiratory pathology.

The pulmonary histopathological changes differed primarily among sheep from the different groups in the amount of lung affected by lungworm activity, the types of tissue response to parasitic life stages and bacteria and the degree and chronicity of bacterial bronchopneumonia. The major changes involved small airways, interstitial tissue and the locally diffuse inflammatory reactions to *P. stilesi* reproduction.

Lesions of bacterial bronchopneumonia in sheep from the three herds were similar. They were characterized by a lobular consolidation and atelectasis and diffuse interstitial thickening. Bronchioles were often distended with mucoid material, sometimes containing neutrophils (Figure 3). A similar material with macrophages was also often within partially collapsed alveoli. Neutrophils were rare, but when present formed small aggregates in airways and alveoli (Figure 4). The bronchiolar submucosa and peribronchiolar tissues contained mononuclear cells in varying numbers. Pleural fibrosis was usually present.

Columbia Lake

Bighorn sheep from the CL herd had histological changes caused by hepatic and intestinal parasitism to a degree similar to those in the other herds (Table 4). Coccidial organisms were present in only one lamb. Renal and abomasal inflammation was mild and rare. There was mild mononuclear cell infiltration of the tracheal submucosa in CL 2. Tiny foci of epithelial necrosis were present. There did not appear to be any association of the lesion with other respiratory tract changes or clinical signs in this animal.

There was no evidence of infection by *Sarcocystis* spp. or lesions suggestive of active contagious ecthyma in this herd. Lymphoid hyperplasia was usually present to a moderate degree.

Table 1. Selection criteria of bighorn sheep collected from three herds in the East Kootenays in 1983-84

Sheep number	Age (yr.)	Sex	Body weight (kg)	Body condition[a]	Haircoat	Symptoms
CL 1	2.5	M	77	G	long, patchy	
CL 2	0.5	M	41	G-E		
CL 3	0.5	M	33	G-E		small size
CL 4	4.5	F	73	F	long, thin	ocular discharge suspected
CL 5	1.5	M	65	F-G	long, rough, yellow	
CL 6	3.5	F	71	G-E	patchy	few dry coughs
WW 1	0.5	M	29	VP-P	rough, yellow	isolated, lethargic nasal discharge, CE[b]
WW 2	3.5	F	72	F	long, rough, pale	
WW 3	0.5	F	15	VP-P	long, rough	isolated, lethargic weak, nasal discharge, CE, diarrhea
WW 4	6.5	F	65	F		CE
WW 5	3.5	F	65	F	yellow	CE, diarrhea
WW 6	1.5	M	53	F	long, pale	isolated
ER 1	0.5	F	24	G		
ER 2	4.5	F	67	F-G		
ER 3	3.5	F	68	G		
ER 4	1.5	M	42	G	pale	small size
ER 5	7.5	F	82	G		
ER 6	9.5	F	73	G		

[a] E = excellent
G = good
F = fair
P = poor
VP = very poor

[b] CE = contagious ecthyma

Table 2. Body condition scores of bighorn sheep collected from three herds in the East Kootenays in 1983-84

	Sheep number	Muscle mass	Fat depots	Total body score[a]
Columbia Lake	CL 1	10	90	100
	CL 2	10	90	100
	CL 3	10	70	80
	CL 4	5	70	75
	CL 5	10	65	75
	CL 6	10	75	85
				* = 85.8 ± 11.6
Wigwam	WW 1	5	30	35
	WW 2	10	80	90
	WW 3	5	10	15
	WW 4	5	80	85
	WW 5	5	65	70
	WW 6	5	45	50
				* = 57.5 ± 29.5
Ewin Ridge	ER 1	10	55	65
	ER 2	10	60	70
	ER 3	10	75	85
	ER 4	10	75	85
	ER 5	10	80	90
	ER 6	10	80	90
				* = 80.8 ± 10.7

[a] Body scores were not significantly different among groups.

Table 3. Preserved kidney and adrenal gland weight ratios of bighorn sheep collected from the East Kootenays in 1983-84

Sheep number	Age (yr.)	Sex	Body weight (kg)	Kidney : adrenal ratio
CL 1	2.5	M	77	= 29.4
CL 2	0.5	M	41	= 37.3
CL 3	0.5	M	33	= 33.0
CL 4	4.5	F	73	= 24.6
CL 5	1.5	M	65	= 26.5
CL 6	3.5	F	71	= 31.7
				* = 30.4 ± 4.6[a]
WW 1	0.5	M	29	= 23.5
WW 2	3.5	F	72	= 23.8
WW 3	0.5	F	15	= 9.4
WW 4	6.5	F	65	= 29.2
WW 5	3.5	F	65	= 19.3
WW 6	1.5	M	53	= 25.5
				* = 21.8 ± 6.9[b]
ER 1	0.5	F	24	= 34.2
ER 2	4.5	F	67	= 26.3
ER 3	3.5	F	68	= 26.1
ER 4	1.5	M	42	= 27.8
ER 5	7.5	F	82	= 26.7
ER 6	9.5	F	73	= 26.7
				* = 28.0 ± 3.1[a,b]

[a,b] Values with different superscript letters are significantly different.

PLATE 1

Figure 2. Hepatic lesion including portal fibrosis, bile duct hyperplasia (arrows) and mononuclear cell infiltration typical of that found in many sheep. x 16. H & E.

Figure 3. Focal area of bronchopneumonia characterized by lobular consolidation, diffuse interstitial thickening, mononuclear peribronchiolar infiltrations and bronchiolar exudate. x 6.3. H & E.

Figure 4. Small intraalveolar aggregates of neutrophils mixed with mucus and macrophages in bronchopneumonia caused by ***Pasteurella haemolytica*** x 16. H & E.

2
3
4

The lungs of the six CL sheep examined had many small airways which had marked fibromuscular hyperplasia of the muscularis mucosae. The epithelium had frequently undergone squamous metaplasia and the lumen sometimes contained a mucoid exudate, with or without larvae of *Protostrongylus* spp. nematodes (Figure 5). Mucosal hyperplasia was a relatively uncommon change compared to lung sections from the other herds. Cuffs of mixed lymphocytes and plasma cells frequently surrounded the airways and adjacent vasculature. Activated lymphoid follicles were prominent around airways, vessels and especially within the interstitium.

The interstitial tissue was often thickened, primarily by hyperplasia of fibromuscular elements and considerable fibrosis. Mixed mononuclear cells infiltrated the expanded interstitium.

Acute inflammatory changes were rarely seen in alveolar spaces. Alveoli usually contained differentiated macrophages. The alveolar lining cells were commonly cuboidal, probably type II pneumocytes.

Large numbers of adults, larvae and ova of *P. stilesi* were present in the CL sheep. The granulomatous inflammatory response to these life stages consisted of large numbers of eosinophils, lymphocytes and plasma cells in equal proportions, with fewer giant cells (Figure 6). The cell types associated with each life stage did vary but this aspect was not considered separately in this study.

A mild, focal bronchopneumonia was present in CL 6. An identifiable protostrongylid larva was located within the area of reaction.

Wigwam

Parasitic lesions of the liver, abomasum, intestines and muscles were present in all sheep from the WW range (Table 4). Five of six sheep had coccidial organisms visible in sections of small intestine. Renal lesions were present in all sheep; however, the most severe and extensive were in WW 1, 4 and 5 and were associated with primary disease in other organs. Areas of chronic inflammation were noted on gross examination of the kidneys of WW 1. Histologically these were severe infiltrations of mononuclear cells and fibrous connective tissue extending through the cortex. Glomeruli and tubules were obliterated locally. The remaining areas appeared normal except for tubular casts in some tubules.

There was mild mononuclear cell infiltration of the tracheal submucosa in three of five sheep examined. Moderate inflammation of the trachea was present in two sheep. One of these, the lamb WW 1, had an active suppurative tracheitis with epithelial hyperplasia and metaplasia as well as neutrophil and lymphocyte infiltration.

Table 4. Severity of histopathologic changes in the tissues of bighorn sheep from the Columbia Lake, Wigwam and Ewin Ridge herds in southeastern British Columbia in 1983

Lesions	SPECIMEN[a]																	
	Columbia Lake						Wigwam						Ewin Ridge					
	CL 1	CL 2	CL 3	CL 4	CL 5	CL 6	WW 1	WW 2	WW 3	WW 4	WW 5	WW 6	ER 1	ER 2	ER 3	ER 4	ER 5	ER 6
Hepatitis																		
- periportal	++[b]	+	+	+	+++	+++	++	+	+++	+	++	+++	+	++	+	+	++	+++
- focal	+	+++			++	+++	+	+	+	+	+++[e]	+		+++	+	+	+++	++
Renal																		
- glomerulitis		+					+	+++	++	+	++	++		+			+	++
- nephritis							+++	+		d	+++[e]	+			+		+	+
Lymphoid hyperplasia																		
- retropharyngeal node		++	++	++	+		++	++	f	d	++[e]	++	++	+	+	++	+[g]	+
- mediastinal node		+++	++	++	++		++		f	d	++	++	++	+	++	++	++	++
- mesenteric node		+++	++				++	+	f	d		++	++		+	++	+	
- spleen		++	++	++			+	++	f	d	++[e]	++	++	+	+++	++	+	
- Peyer's patches		++	++		++		++		f				++		++	++		++
- nasopharynx		++	++	++	++	++	++	++	++		n.d.	++		+		++		++
- epithelial changes					++	++	++	++	++	++	n.d.	+		+		++[g]	+	++[g]
Tracheitis		+					++	+	n.d.	+	+	++					+	
Abomasitis		+		+			++	++	+++	+[d]	+++	++	+	+	+	+++	++	++
Parasitic enteritis																		
- small intestine	++	+++[c]	++	++	+++	++	++	+++[c]	+++[c]	++[ce]	+++[c]	+++[c]	+++[c]	+++[c]	+++[c]	+++[c]	+++	+++
- large intestine	++	++	++	++	++	+	++	++	+++	+	++	++	+	+	++	+	++	++
Sarcocystis spp. infection																		
- muscle								+	+	++	++	+++		+++		++	++	++
- heart							+	++		++[d]	+	+		++	+	+	+	++
Contagious ecthyma							+		+	+	+							

[a] severity
[b] + mild; ++ - moderate; +++ - severe
[c] coccidial organisms present
[d] lymphoid tumor
[e] granulomatous reaction
[f] lymphoid atrophy
[g] invasive protozoa present

PLATE 2

Figure 5. Fibromuscular hyperplasia of small airway in lung infected with *Protostrongylus stilesi*. Squamous metaplasia of airway mucosal cells was common in these lungs. x 16. H & E.

Figure 6. Chronic inflammatory response to various life stages of *Protostrongylus stilesi*. x 6.3. H & E.

Figure 7. Diffuse infiltration of myocardium of sheep WW4 by large atypical lymphoid cells. x 16. H & E.

Figure 8. Granulomatous foci in renal cortex of sheep WW5. Central mineralized areas are surrounded by giant cells, epithelioid cells, lymphocytes and plasma cells. x 6.3. H & E.

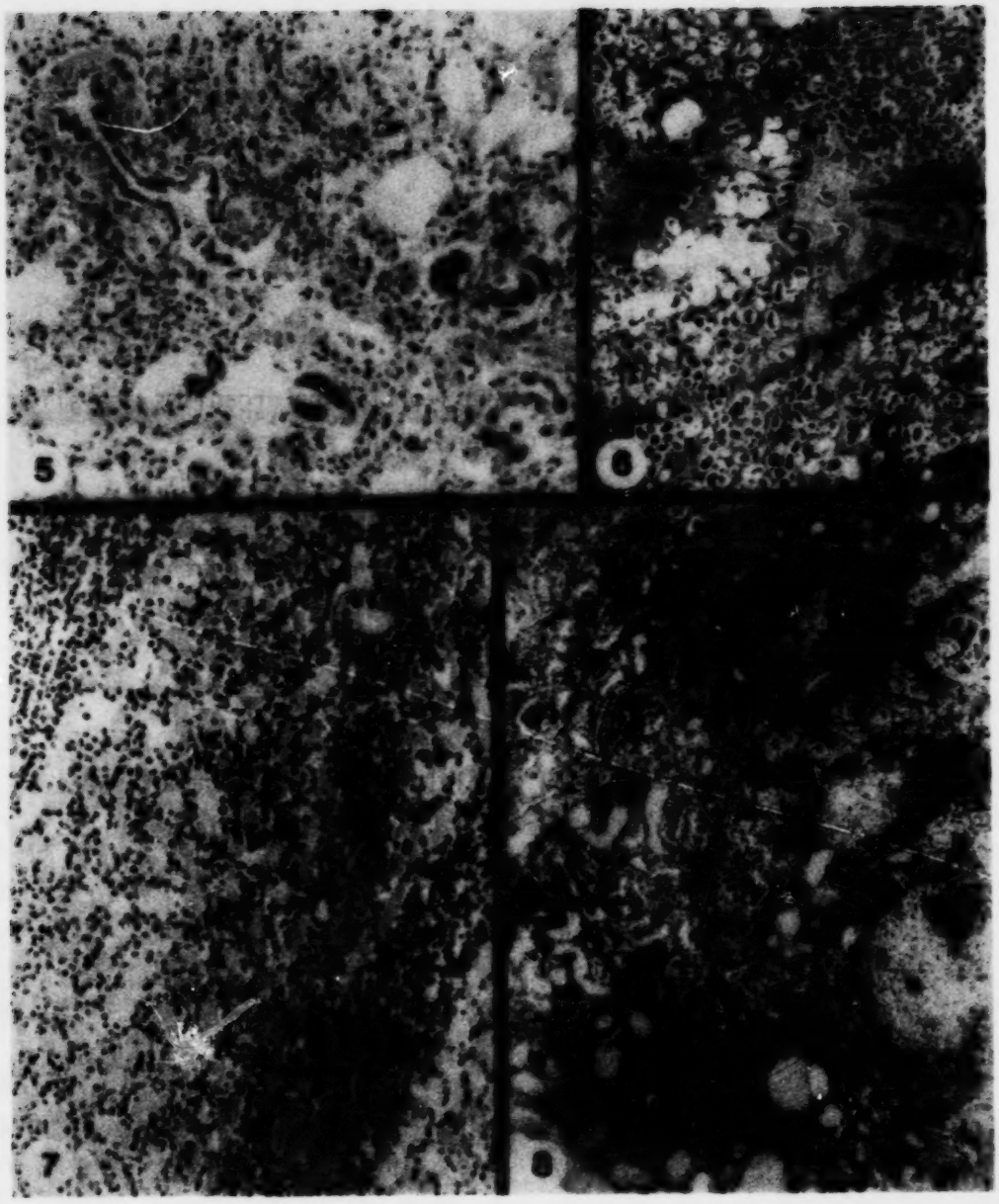

5
6
7
8

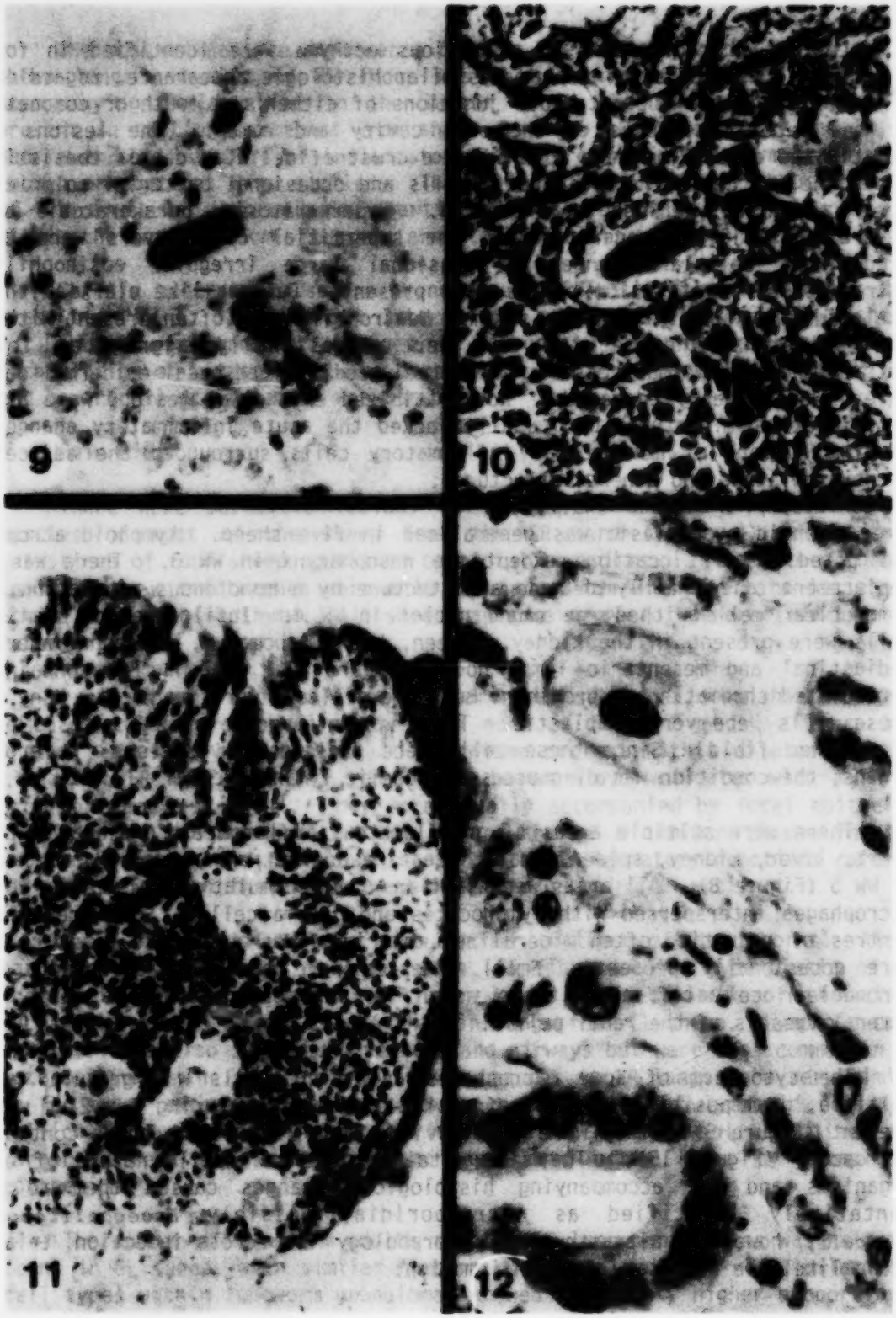
PLATE 3

Figure 9. Gram positive organisms (1 x 2 um) (arrow) within renal tubular cells of sheep WW5. Brown and Brenn stain.

Figure 10. Same section under polarized light. The organisms are slightly birefringent. x 60. Brown and Brenn stain.

Figure 11. Ciliated protozoa (arrows) within the pharyngeal submucosa of sheep from Ewin Ridge. These parasites were usually associated with focal epithelial and lymphoid cell necrosis. x 40. H & E.

Figure 12. Ciliated protozoan within dilated abomasal gland of sheep ER 4. x 100. H & E.


9
10
11
12

Lesions characteristic of contagious ecthyma were identified in four sheep. All lesions examined had a similar histologic appearance, regardless of location on the mucocutaneous junctions of either the mouth or coronets, or the mucosal surfaces of the oral cavity and rumen. The lesions of keratinized epithelium were covered by a crust of cellular debris consisting of epithelial cells, necrotic neutrophils and occasional bacterial colonies. Focal areas were eroded or ulcerated. Hyperkeratosis, parakeratosis and severe ballooning degeneration of the superficial cell layers were the predominant cellular changes. Occasional large irregular eosinophilic intracytoplasmic inclusion bodies were present. Bullous-like clefts within the epidermis were filled with serum. Neutrophils were often present within the epidermis and dermis, and were occasionally aggregated into intraepithelial microabscesses. The dermal papillae and basal epidermal cell layers were usually edematous. Nonkeratinized epithelial lesions were also proliferative in nature, but usually lacked the acute inflammatory changes. Varying numbers of mononuclear inflammatory cells surrounded the adjacent microvasculature and adnexal structures.

Lymphoid hyperplasia was generalized in five sheep. Lymphoid atrophy was noted in all locations except the nasopharynx in WW 3. There was a replacement of normal lymph node architecture by a monotonous population of mononuclear cells with large round nuclei in WW 4. Infiltrates of similar cells were present in the kidney, spleen, heart, abomasum, retropharyngeal, mediastinal and mesenteric lymph nodes (Figure 7). The nuclei contained reticulated chromatin and prominent multiple nucleoli were frequent. Many of these cells were very anaplastic. There was an average of 2-3 mitoses per high power field. Since these cells were present in vessels in numerous organs, the condition was diagnosed as leukemic lymphosarcoma.

There were multiple areas of granulomatous inflammation present in the heart, liver, kidney, spleen, small intestine and retropharyngeal lymph node of WW 5 (Figure 8). All areas were similar with accumulations of epithelioid macrophages interspersed with lymphocytes and plasma cells. Some areas had centres of necrotic, often mineralized material. Multinucleate giant cells were occasionally present. Small arteries were sometimes surrounded by mononuclear cell cuffs and there were fibrinoid changes in the walls of several vessels of the renal pelvis.

The cytoplasm of some macrophages and giant cells was granular and multiple, gram positive, mildly refractile organisms measuring 1 x 2 um were present (Figure 9). They were more obvious when viewed with phase contrast microscopy (Figure 10). The size, staining and refractile nature of the organisms and the accompanying histological changes caused them to be tentatively identified as microsporidia, possibly *Encephalitozoon cuniculi*; however, ultrastructural morphology and cross-infection trials would likely be necessary for confirmation.

The most remarkable difference between the histopathology of CL and ER sheep lungs and that of WW sheep was the paucity of lungworm stages and accompanying inflammation in the latter herd. No adult *P. stilesi* were present in sections examined from sheep from WW. Compared to CL and ER, WW had fewer total numbers of inflammatory cells present in lungworm granulomas, though proportions were similar. These lungs had a markedly reduced amount of fibromuscular hyperplasia, particularly surrounding airways, but also within the interstitium. Less interstitial fibrosis was also noted.

Chronic moderate to severe bronchopneumonia with fibrous pleuritis were present in WW 1, 3, 4 and 5. Interstitial tissue was thicker in WW sheep, but chronic inflammatory changes of alveolar cell hyperplasia and the accumulation of macrophages were decreased. Acute inflammation with necrosis and neutrophil accumulation was rare.

Ewin Ridge

There were parasitic lesions in the liver, abomasum, intestines and muscles of most of the sheep from the ER herd (Table 4). The small intestines of four sheep contained coccidial organisms. Inflammatory changes in the kidney and trachea were mild and sporadic. There were no lesions of active contagious ecthyma. All sheep had some degree of generalized lymphoid hyperplasia.

Protozoa were found within the pharyngeal submucosa or within an artery adjacent to the retropharyngeal lymph node of ER 4, 5 and 6 (Figure 11). They appeared to be identical to organisms present within dilated abomasal glands of ER 4 (Figure 12). The protozoa were oval ciliates with a large, prominent macro-nucleus. They were usually accompanied by focal epithelial and lymphoid tissue necrosis. I am unaware of a similar tissue invasive protozoan species and feel that the localized inflammatory reactions rule out the possibility of the presence of the protozoa being an artifact.

Lungs from ER sheep were most similar to those of CL bighorns. Airway pathology also included a large amount of fibromuscular hyperplasia of the muscularis mucosae. Epithelial hyperplasia and metaplasia of the airway mucosa was a more common change than in lungs from CL sheep. Lymphoid cuffs and follicles also surrounded vessels and airways but were less common in the interstitium. The interstitial tissue changes in ER lungs were very similar to CL sheep except for a much lower concentration of lymphoid cells and follicular development within the interstitium. The alveoli contained even larger numbers of macrophages and were more often lined by metaplastic epithelium.

The number of lungworm adults seen in ER lungworm nodules was half that found in CL sheep, with similar numbers of larvae and ova. The inflammatory cell types within lungworm granulomas showed a slightly higher proportion of

giant cells, but was otherwise of equal numbers of eosinophils, lymphocytes and plasma cells.

Resolved focal bronchopneumonia was present in ER 5 and 6. There was no involvement of the pleura in either case and few remaining inflammatory cells.

LABORATORY ANALYSES

Microbiology

No significant pathogenic organisms were cultured from lymph nodes, respiratory tissues or swabs from CL sheep. A pure culture of low numbers of *Escherichia coli* was recovered from the hepatic abscess in CL 4.

Pasteurella haemolytica biotype T of a nonhaemolytic variety was recovered from the bronchial swabs and right cranial lung of WW 1 and the retropharyngeal lymph node of WW 4. A haemolytic biotype of *P. haemolytica* was cultured from the bronchial swabs, mediastinal lymph node and left cranial lung of WW 4. *Staphylococcus aureus* was recovered from the mediastinal lymph nodes and bronchial swabs of WW 4, retropharyngeal lymph nodes of WW 3, 4, and 5 and joint swabs of WW 3. All other lung cultures from WW sheep were negative or produced insignificant contaminants.

The retropharyngeal lymph node and right and left middle lung lobes of ER 5 contained a nonhaemolytic *P. haemolytica* biotype T, biochemically similar to the WW 1 and the WW 4 isolates. There were no other significant organisms recovered from ER sheep.

No viruses were recovered from any of the sheep tissues cultured. Positive titres to PI_3 virus were found in serum from WW 2 and 6 and ER 2, 5 and 6. Sheep ER 6 also had a weakly positive titre to RSV virus. All sera were negative to IBR, BVD, Johne's disease, maedi/visna, EHD and BT viruses. There was no antibody to bovine lymphosarcoma virus in sera from WW 4.

Parasitology

Fecal flotations indicated negative to very high levels of nematode and/or protozoal gastrointestinal parasitism (Table 5). Ova of *Marshallagia*, *Nematodirus* and *Trichuris* spp. and oocysts of *Eimeria* spp. were recovered, often in mixed infections. The levels were higher in younger animals, particularly those with systemic illnesses (WW 1 and 3).

The number of *Protostrongylus* spp. larvae present in feces was higher in CL sheep than in WW or ER sheep, with average numbers of larvae per gram of feces of 799 (CL), 162 (WW) and 166 (ER). Lambs and yearling bighorns from CL had the highest larval outputs, while the lambs from WW and the lamb and yearling from ER had very few larvae in their feces. The WW yearling had moderate numbers of larvae.

Trace Minerals

The selenium level in liver tissues from all CL sheep was less than or equal to 0.11 umoles/g, levels that are considered deficient in domestic

sheep (Table 5). Livers of sheep WW 1, 4 and 5 contained selenium in levels considered marginal. All ER bighorn sheep appeared to have adequate levels of selenium (Table 5).

Tissue copper was at a marginal level in CL 2 and 5, WW 2, 3 and 4 and ER 1, 2, 5 and 6 (Table 5). Zinc levels in liver were marginal in CL 6, WW 1, 3, 5 and 6 (21 - 29 umoles/g).

Chemistry

Blood urea nitrogen values were within normal domestic sheep levels in only two CL (CL 2 and 3) and two ER sheep (ER 1 and 6) (Table 6). Values were higher than normal in WW 1, 3 and 4. The remainder of bighorn sheep in all three herds had lower than normal values. Serum glucose was mildly to moderately increased in five CL, four WW and four ER sheep. Two ER sheep had extremely high glucose levels.

Total serum protein levels were reduced in four CL, four WW and two ER bighorns. The average values were highest in the ER herd and lowest in the CL herd. Fecal nitrogen was very consistent in the CL and ER sheep herds with average values of 1.0 and 1.8%, respectively. The fecal nitrogen content varied more among WW sheep, especially in those with clinical diseases (WW 1 and 3). The average level for this herd was 1.1%.

Serum and urine cortisol values varied greatly within herds without a consistent pattern. Kidney:adrenal ratios were similar in CL and ER bighorn sheep but were lower on average in WW sheep, indicating larger adrenal size in sheep from the WW range (Table 3).

Table 5. Number of lungworm larvae per gram of feces and copper and selenium concentrations (wet weight basis) in liver of bighorn sheep collected from the East Kootenays in 1983-84

Sheep	Larvae/g of feces	Copper (umole/g)	Selenium (nmol/g)
CL 1	172	1.21	1.27
CL 2	665	0.22	1.27
CL 3	1971	1.05	0.76
CL 4	543	0.68	0.89
CL 5	959	0.31	1.39
CL 6	484	1.15	0.76
$\bar{x}$	799 ± 628[a]	0.77 ± 0.50	1.06 ± 0.26[a]
WW 1	9	1.43	2.03
WW 2	58	0.25	4.05
WW 3	3.5	0.27	3.67
WW 4	167	0.10	3.17
WW 5	321	0.58	2.41
WW 6	414	0.99	7.73
$\bar{x}$	162 ± 172[b]	0.60 ± 0.66	3.84 ± 2.85[b]
ER 1	13	0.10	3.80
ER 2	347	0.13	3.42
ER 3	142	0.50	4.05
ER 4	51	0.37	3.80
ER 5	109	0.13	3.67
ER 6	336	0.09	3.67
$\bar{x}$	166 ± 143[b]	0.22 ± 0.20	3.73 ± 0.32[b]
Normal[c]	deficient	0.01 - 0.06	0.06 - 1.27
	marginal	0.08 - 0.31	1.90 - 3.17

[a,b] Values with different superscript letters are significantly different.

[c] Concentration of copper and selenium considered marginal and deficient in liver of domestic sheep (Puls 1981).

Table 6. Serum, fecal and urine chemistry values in bighorn sheep collected from the East Kootenay region in 1983-84

Sheep number	Blood urea nitrogen (mmol/L)	Total protein (g/L)	Fecal nitrogen (%)	Glucose (nmol/L)	Cortisol (ng/ml)	
					serum	urine
CL 1	1.0	50	0.9	4.3	3.6	18.2
CL 2	3.9	57	1.0	4.3	7.2	63.5
CL 3	4.1	46	1.0	3.9	< 1	66.5
CL 4	1.4	61	1.0	3.9	< 1	NE[c]
CL 5	1.0	42	1.1	3.6	9.5	60.3
CL 6	0.4	64	1.1	2.9	12.8	12.8
*	1.9 ± 1.6	53.3 ± 8.7	1.0 ± 0.1[b]	3.8 ± 0.7	ND[c]	ND
WW 1	8.9	57	1.8	3.1	15.6	77.5
WW 2	2.7	60	0.8	4.0	3.1	NE
WW 3	6.9	61	0.5	2.9	23.8	178.8
WW 4	10.2	46	1.4	4.5	0.3	39.9
WW 5	1.2	58	1.1	3.3	1.0	NE
WW 6	1.2	58	0.9	6.0	1.2	41.1
*	5.2 ± 4.5	56.7 ± 5.4	1.1 ± 0.5[b]	4.0 ± 1.3	ND	ND
ER 1	3.5	78	2.0	3.3	5.9	NE
ER 2	1.3	66	1.8	6.0	22.4	NE
ER 3	0.7	63	1.7	34.7	2.6	NE
ER 4	1.1	61	1.4	5.2	27.2	31.2
ER 5	2.0	56	1.8	2.6	16.9	NE
ER 6	3.8	57	1.8	18.1	32.1	NE
*	2.1 ± 1.5	63.5 ± 8.0	1.8 + 0.2[a]	11.6 ± 16.1	ND	ND

[a,b] Values with different superscript letters are significantly different.

[c] NE - not examined; ND - not determined.

DISCUSSION

The CL herd was expected to be present in large numbers on its small traditional range during the winter of 1983. There were reports of respiratory disease and reduced numbers of bighorn sheep in other herds to the southeast of Columbia Lake during the previous winter. It was believed that some of these herds shared summer ranges or migration routes with CL sheep, and that contact and transmission of respiratory pathogens between herds was very likely to occur. In addition, the CL winter range was considered to have been badly overgrazed for many years; however, individual sheep had shown no signs of inadequate nutrition. Annual lamb:ewe ratios had been decreasing, but lambs were of large size and ratios remained higher than those of other E.K. herds. Despite the suspicion that these factors could predispose the CL herd to a disease outbreak in 1982 or 1983, there was no indication of clinical or subclinical disease in these animals.

In this study, the CL bighorn sheep occupied their winter range at a high density. Animals were in large groups and appeared to remain calm, moving little even immediately following disturbances. This behaviour had been typical of bighorn sheep in this location. Clinical signs expected to distinguish animals with disease or decreasing body condition were restricted to slight variations in the degree of body muscling, fat deposition and coat colour. A single ewe had a mild cough. The field observations alone suggested that the animals in the CL herd were in good health.

In contrast, there appeared to have been little increase in the WW population following the dieoff. Occasional clinical disease had been reported prior to the study observations and very few lambs were identified during the spring counts. The winter range had appeared to improve with the reduced density of both sheep and competitive ungulate species. The WW herd was suspected to have experienced the most severe effects of the pneumonia dieoff, and it was believed that the herd was in, or about to enter a phase of increased population growth with minimal danger of further health problems.

The WW sheep were present in scattered small groups on the large open winter range when evaluated for the study. They were flighty and difficult to observe and approach, even without disturbance. Prior to the 1981-82 dieoff, observations made of this herd confirmed that they grazed as large groups which tolerated human approach in a manner similar to the CL sheep. There appeared, then, to have been a radical change in the behaviour of sheep on the WW range. It is possible that the reduction in the total number of WW sheep increased both the nervousness and flight distance, and that the difference in behaviour between the two herds was a simple reflection of herd density and range topography.

The clinical signs in sheep sampled from WW included pale coats, tick infestation, obvious loss of condition and weakness, nasal discharge, diarrhea and active contagious ecthyma lesions in all ages. The only lambs observed were collected because of combinations of all of the above signs. It was concluded that there was a high proportion of WW sheep in obvious poor health, and that lamb mortality was close to 100% by the time the lambs were 6 months of age. The WW herd appeared to be suffering considerable residual effect of the dieoff, and it appeared that any recovery growth phase would be delayed.

Ewin Ridge bighorn sheep had remained at a relatively stable population level for at least the past 13 years. They primarily utilized accessible snow-free areas as traditional winter range. Animals were grouped on slopes where dispersal was limited by the amount of surrounding snow accumulation. Previous observations had not described large scale mortality, clinical disease or any signs of reduced body condition. This herd did not suffer from the periodic pneumonia dieoffs seen in the other E. K. sheep herds, but there was no further information available on their health.

The use of a helicopter in the study prevented the visualization of natural groupings and clinical signs at the time of collection. The lamb and yearling examined were small compared with their age classes in the other herds, but the carcasses were in good condition. No other clinical or external signs were apparent and no conclusions were made from the data available on the ER sheep prior to necropsy. The ER herd did not appear to exhibit any obvious health problems.

The necropsies of study sheep allowed more accurate estimations of body condition than external examination of live animals or unopened carcasses. This will be discussed below. It also allowed assessment of the degree of pulmonary involvement by both parasitic and bacterial pneumonic processes and the presence of other systemic diseases.

The most common gross pathologic lesions in sheep collected from all three herds were parasite-induced focal granulomatous pneumonia, diffuse chronic gastroenteritis, miliary hepatitis and biliary cestodiasis. Microscopic parasitic lesions in the gastrointestinal tract and liver were similar in type and varied only in degree in all sheep. Lesions and parasitic species were found by histopathology but not always identified during the gross examinations and fecal evaluation of each animal. There appeared to be little correlation between the gross appearance and the severity of histologic lesions. These widespread changes in the gastrointestinal tract and liver appeared to have minor effects on animal condition.

Gross examination indicated that the lungs of CL sheep of all ages were the most severely affected by lungworm infection. The lesions associated

with *P. stilesi* in ER sheep lungs were not as extensive and WW sheep were little affected by this parasite.

The histopathology of lungs from sheep from ER demonstrated more airway epithelial hyperplasia and metaplasia, increased alveolar epithelial metaplasia and higher numbers of alveolar macrophages than lungs of sheep from CL. In addition, less lymphoid tissue and follicular development was present around airways and within the lung interstitium of sheep from ER . Pulmonary granulomas in these sheep also contained adult lungworms and more giant cells. Sheep from WW had markedly fewer lungworms and accompanying inflammation, as well as fewer chronic changes associated with the parasite (i.e. fibromuscular hyperplasia).

The most remarkable difference between the histopathology of CL and ER sheep lungs and that of WW sheep was the paucity of lungworm stages and accompanying inflammation in the latter herd. No adult *P. stilesi* were present in sections examined from sheep from WW. Fewer inflammatory cells were present in lungworm granulomas in this herd, compared to CL and ER. These lungs had a markedly reduced amount of fibromuscular hyperplasia, particularly surrounding airways, but also within the interstitium. Less interstitial fibrosis was also noted.

Airway epithelium in WW sheep was markedly more hyperplastic and more often contained exudate than in CL or ER sheep. Mucosal metaplasia, however, was slightly less common than in CL sheep, and only half as common as lungs from ER bighorns. Lymphoid tissue around airways and in the interstitium was as common as in CL sheep, but activated follicles in all locations were rare.

The increased degree of histopathological epithelial changes in the airways and alveoli of lungs from ER sheep was indicative of chronic irritation of these surfaces. This type of injury could result from the presence of large numbers of protostrongylid larvae moving proximally from more distal air passages, as would occur following their maturation in the pulmonary parenchyma. Together with the reduced amount of activated lymphoid tissue and large amount of grossly visible pleural fibrosis, these changes suggest that the ER sheep were in a resolving phase of prior parasitic lung injury. The gross and histologic changes in the CL sheep were believed to indicate chronic but active parasitic injury.

These microscopic pulmonary changes together with information on fecal larvae numbers were considered to support the gross estimations of lungworm infection severity and chronicity in the three herds. The assessment of the degree of lungworm involvement also matched the clinical picture in each herd. Columbia Lake sheep undoubtedly harboured *P. stilesi* infections year round; however, they may also have been subject to heavy reinfection when concentrated on the small, shortcropped winter pasture. Ewin Ridge

sheep may also suffer from high levels of lungworm at certain times of the year, but are less highly concentrated on a winter range of better quality. Less than ideal conditions for larval survival at this altitude, less contamination of the range because of lower sheep density and lower availability of larvae due to better forage condition are likely all responsible for reducing the level of infection at this season and location. At the time of this study, WW bighorn sheep were widely dispersed on a range of improving quality. The sheep in this herd with heavy lungworm burdens probably succumbed during the previous dieoff. These factors may account for the low lungworm infection rate on this range.

Gross and microscopic tissue changes caused by chronic bacterial pneumonias were most severe and extensive in WW lambs. The chronic pneumonias of adult sheep from all three ranges varied in severity and extent. There was localization to single lung lobes in CL and ER ewes. The mild chronic bacterial pneumonia seen in ewes from ER appeared extremely well localized without secondary lesions elsewhere, and were present in what appeared to be clinically normal animals. The focal pneumonia in the single CL ewe was acute, but was also well localized and the animal appeared clinically normal.

The localized pneumonias in CL and ER ewes suggested an association with focal injury and inflammation. This type of lesion can result from the aspiration of protostrongylid larvae produced from established lungworm nodules in more distal areas of the lungs. Fragments of larvae surrounded by focal granulomas or secondarily invaded by opportunistic bacteria have been present, usually in the anterior lung lobes, as clinical or incidental lesions in many bighorns at necropsy (Spraker 1979). The presence of lungworms has historically been considered to predispose the sheep to the colonization of respiratory pathogens (Marsh 1938; Post 1962; Forrester 1971). Focal granulomas presumed to be caused by larvae were occasionally seen in this study; however, the foci were small and usually without changes related to secondary bacterial infection. The focal pneumonia in CL 6 was the only such lesion visible grossly and it did contain larval remnants. No bacteria were cultured from this area.

In contrast, pneumonia in WW ewes, when present, affected more than one lung lobe, extended into the pleural cavity and appeared to be of longer duration. These animals were in poor condition or had signs of disease in other body systems. Microscopic changes in chronic bacterial pneumonias were, however, similar in all herds and varied only in the amount of fibrous tissue present or the age of the lesion.

Bighorn feces have been examined for lungworm LPG to determine parameters such as mean LPG, LPG seasonal annual trends and the proportion of heavily infected sheep per herd to estimate herd infection levels (Uhazy *et al.* 1973; Holmes and Samuel, 1974). These studies and others (Forrester

and Senger 1964; Samson and Holmes 1985) have concluded that individual and herd lungworm larvae output are dynamic and undergo seasonal and annual trends. Single fecal LPG counts can only give rough estimates of herd infection levels.

Pasteurella haemolytica type T, a bacterium strongly associated with the recent B.C. and Alberta dieoffs (Onderka and Wishart 1984), was present in a lamb from WW with active pneumonia and was cultured from lymphoid and lung tissues of WW 4 and ER 5, both of which were ewes with chronic pneumonia. The presence of the organism in the lung of WW 4, in association with *P. haemolytica* and *Staphylococcus aureus*, also an opportunistic pathogenic bacterium, may be incidental since the functional capacity of the immune system of this ewe may have been compromised by a systemic lymphocytic tumor. The presence of the unique T biotype in the focal, mild, resolving lesion in an otherwise healthy ER ewe, supports the hypothesis that *P. haemolytica* type T is an opportunistic pathogen (Onderka and Wishart 1984), and that pneumonia can occur and resolve in individual bighorn sheep without outbreaks of disease.

The high prevalence of chronic diseases, secondary infections, contagious ecthyma, and the continued presence of bacterial lesions within the lungs of adult and juvenile WW sheep in 1983 strongly suggests residual effects of stressors associated with the acute dieoff in 1982. Spraker *et al.* (1984) described the mortality of bighorn lambs in captive and free-ranging herds during years following all-age dieoffs. Lambs less than 6 months of age in their study died with bronchopneumonia caused by opportunistic bacteria and showed marked atrophy of the thymus gland. The presence of thymic and lymphoid atrophy, secondary infections, contagious ecthyma and high gastrointestinal parasitism led to the diagnosis of immunosuppression in the young WW animals in this study. Spraker *et al.* (1984) suggested that stressors similar to those which precipitated all-age dieoffs may continue to affect pregnant ewes. Continuous high levels of glucocorticoids secreted by a highly stimulated adrenal gland may inhibit the development of the thymus and immune system of the fetus. In addition, the steroids may restrict the production of colostral antibodies. Without a fully functional immune system and the passive immunity provided by the colostrum, the neonatal lamb would be extremely vulnerable to opportunistic microorganisms. Adult sheep harbouring chronic respiratory or gastrointestinal infections could easily transmit large doses of pathogens to susceptible lambs. The active contagious ecthyma in combination with systemic conditions involving the immune system in two ewes from WW may indicate immunosuppression in these sheep as well.

Longterm stimulation by physical and environmental stresses can cause hyperplasia of the adrenal cortex and enlargement of the gland. In this study estimates of adrenal gland size were made using kidney:adrenal weight ratios. Since kidney weight varies little with body condition, variations in

adrenal size present with age, sex and physical condition were reduced with the use of the ratio. Adrenal glands of WW sheep were significantly larger than those from CL sheep suggesting that these sheep were subject to greater degrees of stress factors. The pattern of lamb and adult bighorn disease and mortality in the WW herd appears to fit the pathogenesis of disease as suggested by Spraker *et al.* (1984) for bighorn herds in a post-dieoff situation.

Serological results and the lack of diagnostic histological evidence in this study suggested sporadic or no exposure of the E.K. bighorn sheep to PI3, IBR, RSV, BT, EHD, BVD, maedi/visna or Johne's disease. It was of note that a ewe (ER 5) from ER with a resolved pneumonia and a ewe (WW 2) and a yearling (WW 6) from WW without lesions of bronchopneumonia not only had antibodies to PI3, but also had lesions of nonsuppurative tracheitis. Three other sheep from WW with chronic bronchopneumonia and one from CL without bacterial pneumonia demonstrated tracheitis without positive titres to PI3. In the cases from WW, the tracheitis likely resulted from extension of the bacterial pneumonias. Other causes of tracheal irritation, such as inhaled dust particles or heavy lungworm larvae activity, may explain the tracheitis in CL 2. On this evidence, we cannot totally rule out viral agents as contributing to mild upper respiratory tract damage.

It is recognized that the soils of the E. K. are generally deficient in selenium and that deficiency syndromes occur in domestic animals grazing on pasture in this area (R. Puls, pers. comm.). Hebert and Cowan (1971) examined mountain goats, forages and mineral licks from the E.K. area and suggested that animals were predisposed to myopathy (white muscle disease) by low levels of dietary selenium. Eastman *et al.* (1971) determined that copper levels in forage plants common on low elevation winter ranges in the E. K. were especially low.

The nutritional requirements of bighorn sheep for trace minerals is unknown and may not be identical to those of domestic sheep; however, values for the latter were used in this study as normals in the absence of specific information.

Copper levels in liver were judged to be marginal in some animals in all three herds, but not in all sheep from any herd. Marginal selenium levels in some WW sheep and deficient levels in all CL sheep suggest that selenium deficiency related disorders may occur in these two herds although no clinical signs of deficiency were observed. Similar levels of copper and selenium were present in tissues from some WW bighorns that died in the E. K. dieoff in 1981 (Davidson 1982). Since then, mineral licks in WW have been supplemented with a domestic sheep trace mineral mix. It is possible that those sheep collected from the WW range had artificially elevated levels of trace minerals and that deficiencies may have played a more important role in the herd prior to supplementation. The consistently higher levels of

selenium present in ER bighorn sheep support the findings of Hebert (1973) that alpine forages contain higher levels of trace minerals than do lower elevation species and suggest that these sheep do not suffer from selenium deficiency.

Serum chemistry profiles for healthy captive and wild bighorn sheep (Davies 1976; Franzmann 1971a; Franzmann and Thorne 1970; Woolf and Kradel 1970), Stone's sheep (Franzmann 1971b), Dall sheep (Foreyt *et al.* 1983) and Nelson desert sheep (McDonald *et al.* 1981), as well as for sick captive and wild bighorn sheep (Woolf and Kradel 1973; Spraker *et al.* 1984) have been examined. In this study, sheep were shot, usually without prior disturbance. Samples were expected to reflect actual physiologic values in CL and WW sheep, whereas the use of a helicopter at ER was expected to cause increases in parameters affected by acute stress, such as serum cortisol and glucose (Franzmann and Thorne 1970), but not total serum proteins and blood urea nitrogen. The chemistry values obtained during the study were compared to the previously reported levels for wild sheep species as well as to those for domestic sheep.

Glucose values in bighorn sheep from the E. K. were similar to those reported in bighorn sheep elsewhere as well as to levels in domestic sheep. Mildly to extremely increased levels were present in some sheep, and were probably caused by excitement prior to collection. The highest levels occurred in sheep from ER herded with a helicopter. Glucose levels also vary with habitat type; however, without forage evaluation, no habitat quality assumptions may be made from these data (Franzmann 1972).

Blood and urine cortisol values varied too greatly for accurate interpretation. Serum cortisol levels were high in some disturbed, clinically ill and chased sheep, although these findings were not consistent and no relationship to the size of adrenal glands in individual animals was evident. Urine cortisol levels should not have been affected by acute stresses; however, they were not available from all animals and the values obtained had not been corrected for urine concentration. There was a trend towards higher cortisol values in the order WW > CL > ER, which does fit the general assessments of this study; however, the diagnosis of stress levels by this method requires much more rigorous sampling technique, larger sample sizes and further research before proper assessments can be made.

The TP of the sheep from ER was within normal limits for domestic and bighorn sheep. It was decreased in CL juveniles and low normal in CL adults. The sick WW lambs had normal TP in spite of their poor body condition, but the TP in these lambs may have been artificially elevated due to dehydration and/or high circulating immunoglobulin levels in response to systemic infections. Other WW sheep had levels of TP in the low normal range, except for low levels in the ewe with lymphosarcoma.

The levels of BUN were low in the majority of the study sheep. Mild increases were present in sick WW sheep, likely due to body protein catabolism. Levels similar to those in CL, WW and ER sheep have been reported in healthy and sick bighorn sheep (Franzmann and Thorne 1970; Spraker *et al.* 1984) and it was suggested that the levels reflected the low protein content of forages. Many of the apparently healthy sheep in good condition from CL and ER ranges had BUN values far below those previously reported. No explanation was apparent for this.

The FN values obtained from bighorn sheep in this study were comparable to the range of values for bighorn sheep on native forage during October to December (Hebert *et al.* 1984). The FN values were significantly higher in ER sheep than in the other groups and corresponded with levels in migratory sheep seen in that study. Values in WW and CL sheep were similar and matched the lowest levels that were found during winter months in sheep evaluated by Hebert *et al.* (1984). Variations in FN of sick WW animals were likely due to nitrogen losses from systemic illness.

Body condition scores at necropsy were high for both CL and ER sheep but were low for WW sheep. The scores gave only a rough indication of overall animal condition and probably reflected the condition of summer range prior to the time of collection. Total protein, BUN and FN were considered to be more sensitive indicators of animal protein stores. The low values of these parameters in CL sheep suggested inadequate protein content in late summer to winter range forage. This substantiates visual estimates of poor quality winter range for this herd (Davidson 1982). Similar findings in WW sheep may reflect variations seen in chronically ill animals, but further investigation of forage protein content is required to substantiate any estimates of range quality by this method. In contrast, low BUN values of ER sheep were present with normal TP and higher FN content than either of the other herds. Hebert (1972) compared high and low altitude forages in the E. K. and found those from high altitude pastures to be of higher nutrient quality. Stelfox (1976) and Schuerholz (1983) assessed the mountain grassland bighorn habitats within the national parks and the E. K. bighorn habitats and found them to be of high productivity and quality. They were also easily available due to the preference of sheep for south-facing, snow-free slopes. Schuerholz (1983) also noted a lack of interspecific competition for forage at this altitude. These findings support the hypothesis that sheep grazing on high altitude pastures have year round access to better quality nutrition. The low BUN values and marginal tissue copper levels do not completely support the presence of higher quality of feed on the ER winter range; however, sample numbers were small without analysis of their particular forage quality. Larger numbers of coordinated samples of forages, soils and animals over time would be required to interpret these results fully, but the study results do suggest differences in the nutritive status of the three herds.

The study was designed to describe and compare the health status of individual bighorn sheep from three herds, to associate the health status with environmental and physiological factors and the overall dynamics of each herd and to select parameters most suitable for future monitoring of bighorn sheep herd health status. Alternatives to the study design involving more controlled protocols may have provided data more amenable to statistical analysis, but were felt to be impractical for the field situation. I believe that the observational approach was the most useful for this situation because of the broadness of the study objectives, the restricted sample size and our aim to keep the methods as close as possible to techniques available to wildlife managers in the field.

The results of this study demonstrated measurable differences between the low and high elevation wintering bighorn sheep herds of the E. K. region of British Columbia. Despite the small sample size, variations in lungworm levels, TP, FN, selenium status and levels of chronic disease were present. The variations appeared to support the assessments of differences in overall herd dynamics and health status. The differences were primarily related to the factors which have been suggested to have predisposed the E. K. bighorn sheep to an all-age dieoff in 1981. These were high animal density, poor nutrition, parasitism and trace mineral deficiencies. High lungworm levels, reduced nutritional indices and lower selenium levels occurred in the CL herd at high animal density. Sheep wintering in lower density at high elevation on the ER range appeared to have access to better quality nutrition and maintained lower levels of lungworm infection. The effects of the 1981 dieoff and the factors believed to predispose the WW herd to the disease outbreak had a more longterm influence than expected. There was residual chronic disease in adult bighorn sheep, a marked reduction in the viability of lambs and evidence of immunosuppression in all age groups. This profile had persisted for at least 3 years post-dieoff, in spite of reduced animal density on winter range and low levels of lungworm infection.

The status of the study herds appeared to be best determined by the use of a group of indices. This study indicates that LPG, FN and liver selenium levels are parameters which can be measured and differ significantly between bighorn herds in the E.K. region. Since LPG and FN can be obtained from noninvasive fecal collections, these parameters are recommended to be assessed in specific herds, over time, with the sampling of blood, tissues and trace mineral assessment reserved for when circumstances allow or indepth investigations are desired (see Recommendation section). Hanks (1981) advised the characterization of population condition by the assessment of physiological parameters together with reproductive capacity, habitat condition and trend. Comparison of the parameters of nutritional condition, parasite levels, reproduction status and habitat condition between bighorn herds over time may then indicate and be used to predict when conditions predisposing to health problems and sheep density move into the critical

range. If educated predictions can be made before dieoffs occur, remedial actions can be carried out to maintain and increase wild sheep populations.

MANAGEMENT RECOMMENDATIONS

HEALTH STATUS MONITORING

The evaluation and monitoring of the health status of any animal herd, whether domestic or wild, must follow a specific program. The livestock industry and veterinarians have developed such programs over the past century to integrate the maintenance and improvement of animal health, production and management. The clinical and subclinical disease problems of bighorn sheep have been shown to have similarities with certain livestock situations. It appears that this species may be suited to the development of basic herd health programs. The following guidelines may be considered and critically assessed over time for desired results to assist the wildlife manager in the maintenance of a healthy and productive bighorn sheep population.

The bighorn sheep population must be evaluated by herd since individual animals are impractical to treat. Wildlife managers should first assess each herd and range separately and group them on the basis of similar animal and environmental factors (i.e. sheep density, range quality). Management actions can then be tailored to suit similar types of herds. A management plan with goals outlining desired sheep numbers, herd use (i.e. hunting, non-consumptive) and intensity of management desirable and possible should be established. Finally, it may be necessary to priorize management actions and herds in order of importance to maximize benefits.

Baseline population statistics are vital for the proper identification of each herd. This must include total numbers, classified counts and reproductive performance. The critical ranges, migration routes and the location of mineral licks used during all seasons should be defined. Ranges of unknown quality of high priority herds should be assessed.

The evaluation of the health status of a bighorn sheep herd involves at least three separate stages:

1. Determine an accurate history of range quantity and quality, bighorn production and disease occurrence for each herd;

2. Establish present status;

3. Follow seasonal and annual protocol to observe trends in range and animal parameters.

These may be best accomplished by:

1. Intensive management herd
   - collect animals (protocol similar to this study)
   - monitor seasonal and annual trends

a. range - forage quantity and quality
b. animal - density
- lamb:ewe ratio
- lamb survival
- feces - fecal nitrogen, larvae per gram
- consider treatment with anthelmintics, trace minerals and/or density reduction

2. Moderately intensive
- monitor seasonal and annual trends
a. range - forage quantity and quality
b. animal - density
- lamb:ewe ratio
- lamb survival

3. Extensive
- monitor seasonal and annual trends
a. range - forage quantity
b. animal - density
- lamb:ewe ratio

The method used in this study may not be indicated for some management or monitoring schemes. The results, however, underline the value of both invasive and non-invasive techniques. Of these, I believe the collection of feces from sheep herds over successive seasons and years remains the most practical and economical method of monitoring the health status of bighorn sheep. Serial fecal LPG will allow the determination of lungworm infection trends. Fecal nitrogen levels have proven useful in determining diet and habitat quality, but require further studies in field situations, again over time. Although blood and urine cortisol levels were not particularly useful in this study, further studies with these, and a potential method for analyzing fecal cortisol metabolites (T. Spraker, pers. comm.), may provide values for baseline cortisol secretion and allow the evaluation of levels which indicate increased herd stress. Necropsy evaluation of freshly dead animals in healthy and diseased condition by collection or hunter kills, the analysis of liver tissue for trace mineral levels and serum collection for more intensive analyses are strongly advised whenever possible. These sampling procedures must, however, be considered only as corollaries to the observation and study of stable and fluctuating sheep herds, their dynamics and range conditions for trends over time.

Columbia Lake

The B.C. Wildlife Branch was advised to treat CL sheep based on high levels of lungworm infection and trace mineral deficiencies found in this study. Decreasing the density of animals on winter range was considered to be an integral part of this action to reduce grazing pressure and in

anticipation of increases in lamb:ewe ratios in subsequent years (T. Spraker, pers. comm.). Sheep on CL winter range were conditioned to eat fermented apple mash during the late winter of 1984. Fenbendazole anthelmintic was added to treat each sheep three times at weekly intervals. Mineral licks had been supplemented with domestic sheep trace minerals since the fall of 1983. Twenty-five bighorn sheep of mixed age and sex were live-captured after the treatment and moved to a suitable unoccupied winter range. Subsequent transplants have since occurred and a second herd has been established.

An additional three CL sheep were collected and a poached animal was examined in the fall of 1984. Similar procedures were performed as described for project sheep. Fecal samples were taken from transplanted sheep and the CL range for lungworm larvae counts.

Three of the CL sheep collected in 1984 had deficient and one had marginal selenium levels. One of the four had marginal copper values. Lungworm larvae numbers were very low in an adult ewe and a yearling (11,91), moderate in one lamb (344) and high in a second (724). Larvae levels in range collected or trapped sheep feces were zero after spring anthelmintic treatment, but returned to near previous levels in some animals by the fall.

Wigwam

Anthelmintic therapy of the WW herd was given low priority due to the small numbers of lungworms present in the study sheep. Trace mineral supplementation of mineral licks was advised. It was suggested that animals in poor condition or demonstrating obvious clinical signs of disease be removed, when observed, to reduce the proportion of chronic disease carriers in the herd. Since it was believed that the majority of ewes were in an upper age class of reducing productivity, it was suggested that transplantation of sheep onto this range be considered. Experience with the introduction of sheep into existing herds in the U.S.A. (T. Spraker, pers. comm.) and Canada (Davidson 1982) has previously resulted in mortality in the native herds. This alternative to natural population regrowth was advised to be used at the WW with caution.

Ewin Ridge

Management recommendations for the ER herd were restricted to the maintenance of present or slightly lower herd numbers. Since intensive procedures such as live-capturing were completely impractical, it was suggested that sheep numbers be controlled by harvest strategies as required. In addition to the established full curl or 8 year old and over ram regulation, a ewe-lamb harvest was suggested.

The adoption of these recommendations into the E. K. bighorn sheep management plan has accomplished some major achievements. The parasite

burden of CL bighorn sheep has been reduced, if not absolutely, at least annually at the most critical time for the production of healthy lambs. Anthelmintic treatment in the late winter not only reduces the number of larvae transmitted to the fetus *in utero*, but also reduces the number of parasites carried to lambing and summer ranges. Lamb:ewe ratios at CL increased after treatment of the herd (P. Davidson, pers. comm.), but it appears that therapy must continue in the face of constant reinfection of sheep from the range and lack of significant changes in selenium and copper levels. At the time of writing, the two new herds created with sheep transplanted from CL after anthelmintic treatment are reported to be extremely successful. The management actions suggested for WW and ER have been undertaken but no marked positive or negative results have been identified.

There is a serious danger that management practices focus excessively on one area. The manipulation of bighorn sheep herds must be coordinated with the management of their habitat. It has been previously stated that habitat loss and deterioration are considered to be primarily responsible for the reduction of bighorn sheep numbers in the E. K. region. If bighorn sheep are to remain as viable populations, major efforts must be directed towards maintaining and improving the lands available to their use year-round. This includes the protection of existing ranges by limiting access, road closures, the acquisition of prime range as reserves, coordinated resource planning with industrial, agricultural, residential and recreational developers and the harvest of competitive ungulate species. The decreased quantity and quality of E. K. sheep winter range can and has been improved since range enhancement techniques such as controlled burning, selective logging and clearing and forage seeding were instituted after the 1960's dieoff and were considerably intensified since 1981. It is imperative that these practises be continued as required to prevent further habitat losses and deterioration. I believe that the intensive management practises used on the E. K. bighorn sheep and their winter ranges have been responsible for assisting in the recovery of the population from approximately 1500 sheep in 1983 to over 2000 in the spring of 1986 (A. Wolterson, pers. comm.). It is vital that the committment to the recovery of the bighorn herds continue and be coordinated with the protection and enhancement of their habitat.

LITERATURE CITED

Bandy, P.J. 1968. Rocky Mountain bighorn sheep losses in the East Kootenay region of B.C., 1965-67. Paper presented to the Northwest Section, Wildlife Society Annual Meeting, Edmonton, Alberta. 19pp.

Clark, R.K., D.A. Jessup, M.D. Kock, and R.A. Weaver. 1985. Survey of desert bighorn sheep in California for exposure to selected infectious diseases. J. Am. Vet. Med. Assoc. 187:1175-1179.

Davidson, P.W. 1982. East Kootenay bighorn sheep progress report. Typewritten report in files of B.C. Fish and Wildl. Branch, Ministry of Environ., Cranbrook. 56pp.

Davies, R.B. 1976. Blood and serum chemistry values of a Poudre River bighorn sheep herd. Pages 9 to 13 *in*:Proc. Biennial Sym. Northern Wild Sheep and Goat Counc., Jackson, Wyo.

Demarchi, D.A. 1970. Principal winter ranges of East Kootenay bighorn sheep. Typewritten report, B.C. Fish and Wildl. Branch, Ministry of Environ., Victoria. 6pp.

Dunbar, M.R., D.A. Jessup, J.F. Evermann, and W.J. Foreyt. 1985. Seroprevalence of respiratory syncytial virus in free ranging bighorn sheep. J. Am. Vet. Med. Assoc. 187:1173-1174.

Eastman, D.S., J.E. Miltimore, and P.J. Brandy. 1971. Mineral levels of developmental stages of some important range forages in southeastern British Columbia. Typewritten report, B.C. Fish and Wildl. Branch, Ministry of Environ., Victoria. 23pp.

Foreyt, W.J., T.C. Smith, J.F. Evermann, and W.E. Heimer. 1983. Hematologic, serum chemisty and serologic values of Dall's sheep (*Ovis dalli dalli*) in Alaska. J. Wildl. Dis. 19:136-139.

Forrester, D.J. 1971. Bighorn sheep lungworm-pneumonia complex. Pages 158-173 *in*:Davis, J.W., and R.C. Anderson, eds. Parasitic diseases of wild mammals. Iowa State Univ. Press, Ames.

Forrester, D.J., and C.M. Senger. 1964. A survey of lungworm infection in bighorn sheep in Montana. J. Wildl. Manage. 28:481-491.

Franzmann, A.W. 1971a. Comparative physiologic values in captive and wild bighorn sheep. J. Wildl. Dis. 7:105-107.

_____. 1971b. Physiologic values of Stone's sheep. J. Wildl. Dis. 7:139-141.

_____. 1972. Environmental sources of variation on bighorn sheep physiologic values. J. Wildl. Manage. 36(3):924-932.

Franzmann, A.W., and E.T. Thorne. 1970. Physiologic value in wild bighorn sheep (*Ovis canadensis canadensis*) at capture, after handling and after captivity. J. Am. Vet. Med. Assoc. 157:647-650.

Hanks, J. 1981. Characterization of population condition. Pages 47-73 *in*: C.W. Fowler, and T.D. Smith, eds. Dynamics of large mammal populations. J. Wiley and Sons, New York.

Hebert, D.M. 1972. Forage and serum phosphorus values for bighorn sheep. J. Range Manage. 25:292-296.

_____. 1973. Altitudinal migration as a factor in the nutrition of bighorn sheep. Ph.D. Thesis, Univ. of B.C., Vancouver. 355pp.

Hebert, D.M. and I. McT. Cowan. 1971. White muscle disease in the mountain goat. J. Wildl. Manage. 35:752-756.

Hebert, D.M., J. Hebert, and M. Caskey. 1984. Fecal nitrogen as a determinant of animal condition in bighorn sheep. Pages 317-340 *in*: Proc. Biennial Sym. Northern Wild Sheep and Goat. Counc.

Holmes, J.W., and W.M. Samuel. 1974. Surveillance study of the parasites of bighorn sheep in the mountain national parks. Final rep., Natl. Hist. Parks and Sites, Calgary, Alta. 22pp.

Howe, D.L., G.T. Woods, and G. Marquis. 1966. Infection of bighorn sheep with myxovirus parainfluenza-3 and other respiratory viruses. Results of serologic tests and culture of nasal swabs and lung tissue. Bull. Wildl. Dis. Assoc. 2:34-37.

Jessup, D.A. 1985. Disease of domestic livestock which threaten bighorn sheep populations. Desert Bighorn Counc. Trans.: 29-33.

Kistner, T.P. 1980. A field technique for evaluating physical condition in deer. Ore. Dep. Fish and Wildl. and U.S. Fish and Wildl. Serv. 13pp.

Kistner, T.P., G.E. Reynolds, L.D. Koller, C.E. Trainer, and D.L. Eastman. 1975. Clinical and serological findings on the distribution of bluetongue and epizootic hemorrhagic disease viruses in Oregon. Proc. Am. Assoc. Vet. Lab. Diag. 18:135-148.

McDonald, S.E., S.R. Paul, and T.D. Bunch. 1981. Physiologic and hematologic values in Nelson desert bighorn sheep. J. Wildl. Dis. 17:131-134.

Marsh, H. 1938. Pneumonia in Rocky Mountain bighorn sheep. J. Mammal. 19:214-219.

Parks, J.B., and J.J. England. 1974. A serological survey for selected viral infections of Rocky Mountain bighorn sheep. J. Wildl. Dis. 10:107-110.

Parks, J.B., G. Post, and E.T. Thorne. 1972. Isolation of parainfluenza virus from Rocky Mountain bighorn sheep. J. Am. Vet. Med. Assoc. 161:669-672.

Post, G. 1962. Pasturellosis of Rocky Mountain bighorn sheep (*Ovis canadensis*). J. Wildl. Dis. 23:1-14.

Robinson, R.M., T.L. Hailey, C.W. Livingston, and J.W. Thomas. 1967. Bluetongue in the desert bighorn sheep. J. Wildl. Manage. 31:165-168.

Samson, J., and J.C. Holmes. 1985. The effect of temperature on rates of development of larval *Protostrongylus* spp. (Nematoda:Metastrongyloidea) from bighorn sheep, *Ovis canadensis canadensis*, in the snail *Vallonia pulchella*. Can. J. Zool. 63:1445-1448.

Samuel, W.M., and J.B. Gray. 1982. Evaluation of the Baermann technique for recovery of lungworm (Nematoda, Protostrongylidae) larvae from wild ruminants. Pages 232-243 *in*: Proc. Biennial Sym. Northern Wild Sheep and Goat Counc., Fort Collins, Colo.

Schuerholz, G. 1983. Elk Valley biophysical inventory. Volume 3: Wildlife. Prepared for Crows Nest Resources Ltd., Calgary. 263pp.

_____. 1984. Annual ecological cycles of Rocky Mountain bighorn sheep populations with high winter ranges in the East Kootenays. Pages 192-210 *in*: Proc. Biennial Sym. Northern Wild Sheep and Goat Counc.

Schwantje, H.M., ed. 1983. Bighorn sheep dieoff workshop proceedings. Typewritten rep., B.C. Fish and Wildl. Branch, Ministry of Environment, Victoria. 41pp.

Spraker, T.R. 1979. The pathogenesis of pulmonary protostrongylosis in bighorn lambs. Ph.D. Thesis. Colo. State Univ., Fort Collins. 233pp.

Spraker, T.R., K. Collins, W.J. Adrian, and J.H. Olterman. 1986. Isolation and serological evidence of a respiratory syncytial virus in bighorn sheep. J. Wildl. Dis. 22:416-418.

Spraker, T.R., C.P. Hibler, G.G. Schoonveld, and W.S. Adney. 1984. Pathologic changes and microorganisms found in bighorn sheep during a stress-related die-off. J. Wildl. Dis. 20:319-327.

Stelfox, J.G. 1971. Bighorn sheep in the Canadian Rockies; a history 1800-1970. Can. Field-Nat. 85:101-122.

_____. 1976. Range ecology of the Rocky Mountain bighorn sheep. Can. Wildl. Serv. Rep. Ser. No. 39.

Uhazy, L.S., J.C. Holmes, and J.G. Stelfox. 1973. Lungworms in the Rocky Mountain bighorn sheep of Western Canada. Can. J. Zool. 51:817-824.

Woolf, A., and D.C. Kradel. 1970. Hematologic values of captive Rocky Mountain bighorns. J. Wildl. Dis. 6:67-68.

_____. 1973. Mortality in captive bighorn sheep - clinical, hematological and pathological observations. J. Wildl. Dis. 9:12-17.

Zarnke, R.L. 1983. Serologic surveys for microbial pathogens. Alaska Dep. Fish and Game Admin. Rep.

Appendix A. Clinical evaluation, gross necropsy and body condition scores of bighorn sheep collected from three herds in the East Kootenays.

COLUMBIA LAKE

Clinical evaluation and condition

CL 1: This young ram was selected on the basis of a haircoat, graded as fair, which was long and patchy over the forequarters and neck. The rump appeared more angular than other sheep in the herd but body condition was graded as good. Muscling and fat deposits were, however, excellent on necropsy.

CL 2: The lamb was considered typical of this age class in the CL herd. The haircoat and body condition were considered good to excellent on clinical and necropsy examinations.

CL 3: This lamb was smaller in size than others in the group. Haircoat and body condition appeared good to excellent; however, on necropsy, fat deposits on the rump, brisket and omentum were mildly depleted, thereby reducing the body score.

CL 4: The ewe appeared to be in fair body condition with a slightly rounded abdomen and an angular rump. The haircoat was considered fair. It was long and rough with mild hair loss and a few scabs over the forequarters and dorsum. A unilateral ocular discharge was suspected but not confirmed at necropsy due to the destruction of the orbits by gunshot. A few tick larvae present on the hide were identified as *Dermacentor albipictus*. General body muscling and fat deposits of the rump, brisket and omentum were reduced.

CL 5: The body muscling of this ram was mildly decreased and there was a yellow, dry appearance to the haircoat. He was graded as fair to good for both categories. Slight hair loss and a few scabs were present over the forequarters. No ectoparasites were observed. Fat was slightly decreased in all body deposits.

CL 6: This ewe was observed in sternal recumbancy and made a series of dry coughs during the period of observation. She appeared to be in good to excellent body condition with a dark, patchy haircoat. No abnormalities of haircoat nor reduction in muscling or fat deposits were present on necropsy.

Gross necropsy

CL 1: There were a few 0.5 - 1 cm diameter raised, pale nodules on the pleural surface of the dorsal caudal lung lobes. Large airways contained *P. rushi* adults. No other abnormal findings were present in other tissues.

CL 2: *Protostrongylus rushi* were present in large airways. Nodules of *P. stilesi* were diffusely scattered throughout all lung lobes and varied in size from 0.2 to 2 cm. Nodules in the distal lobes were small, mottled and translucent whereas the dorsal aspects and the dorsal caudal lobes contained large and often confluent nodules. Full thickness areas of the dorsal caudal lobes measuring 3 x 4 cm were firm, pale and swollen. The overlying pleura was opaque. Small airways on cross section were surrounded by white glistening cuffs. Retropharyngeal, bronchial and mediastinal lymph nodes were enlarged 2-3 times normal size.

The common bile duct was dilated and the wall was thickened. It contained a yellowish mucoid exudate and many mature *W. tetoni*. There were multiple discrete nodules present on the mucosal surface of the abomasum and tiny red nematodes, identified as *Marshallagia* spp. were within the ingesta.

CL 3: *Protostrongylus rushi* adults were also visible within large airways. There were a few 1-1.5 cm nodules along the dorsal aspect of the middle lung lobes. Both caudal lung lobe tips were swollen and white and were well demarcated from normal lung tissue. *Marshallagia* spp. were present in the abomasum in small numbers.

CL 4: Lungworm nodules were present in all lung lobes with heavy concentrations and pleural thickening in the dorsal caudal lobes. Adult *P. rushi* were located in large airways.

The gall bladder was small and the wall thickened. The common bile duct was dilated and the wall was very thickened. Two abscesses measuring 1 and 2 cm and containing layered, greenish, inspissated exudate were within the liver parenchyma adjacent to the gall bladder and bile duct. A large number of *W. tetoni* filled the bile ducts and the proximal duodenum. A few *Marshallagia* spp. were within the abomasal ingesta and the abomasal mucosa was slightly roughened. Multiple 0.1 - 0.2 cm round, white foci were present on the serosal and mucosal surfaces of the cecum and colon. Two 2-3 cm fluid filled cysts, identified as cysticerci, were present on the serosa of the cervix.

CL 5: A large number of *P. rushi* adults were present in airways. Lungworm nodules were almost entirely limited to the dorsal caudal lung lobes and many were fused with thickening of the overlying pleura.

A few *W. tetoni* were present in hepatic bile ducts and several *Moniezia* spp. were in the proximal duodenum. Moderate numbers of *Marshallagia* spp. and small numbers of *Trichuris* spp. were in the abomasum and cecum, respectively. Discrete white, linear foci were present on the cecal and colonic serosae. The adrenal glands appeared slightly enlarged.

CL 6: Adult *P. rushi* were present in airways. There were lungworm nodules in all lung lobes, with concentrations along the dorsal aspect and the dorsal caudal lobes. A small focus in the cranial right lobe was atelectatic with muliple tiny white foci.

Large numbers of *W. tetoni* filled the bile duct. The duct was greatly thickened and dilated. Several white foci were scattered over the cecal serosa.

WIGWAM

Clinical evaluation and condition

WW 1: This lamb moved slowly and his ears were lowered. The poor haircoat stood on end, especially over the neck, and was dry and yellow. A crusty exudate was present around the nares and lips. The body condition was very poor to poor. Necropsy revealed no fat deposits over the rump and brisket and reduced muscling and fat deposits or serous atrophy of fat in the remainder of the carcass. The body score was lower than the clinical examination suggested due to the haircoat standing on end reducing the angularity of the body profile.

The hooves were overgrown. Circular scars and small raised papules were present beneath the nares and along the lips. A single engorged *D. albipictus* was present on the muzzle.

WW 2: This ewe appeared small with an angular rump and was graded to be in fair condition. Her haircoat was also considered to be fair and was pale, long and rough. *Otobius megnini* ticks were present in one ear. Body fat deposits and muscling on necropsy appeared more abundant than determined on clinical examination.

WW 3: The lamb was thin, of extremely small size and considered to be in very poor to poor condition. It stood with a hunched back, lowered ears and moved slowly. The very poor to poor haircoat was long, rough and stood out from the body. A small amount of nasal discharge and crusting of the lips was visible. Fecal staining was present on the perineum and hocks.

A single *D. albipictus* tick was found at the tail base and large numbers of *O. megnini* were within one ear. Proliferative lesions were on both lips, the coronet bands of both forefeet and the right hind foot. Decubitus ulcers were present over the left carpus and both hind fetlocks. All hooves were overgrown. Skeletal muscles were atrophied and almost total serous atrophy of all body fat deposits was found on necropsy.

WW 4: The ewe appeared thin with a more prominent backbone than other animals in the group. She was considered to be in fair condition with a good

haircoat. Both lips drooped with the weight of numerous large proliferative growths. Similar lesions were also present on the dental pad, gingiva, hard and soft palates and several rumen pillars. A single *O. megnini* nymph was found in one ear. Body muscling and rump and brisket fat deposits were only slightly reduced.

WW 5: This ewe was graded as being in fair body and good haircoat condition, appearing thin with a yellowish tinge to the coat. Body muscling and fat deposits were all slightly reduced. There were mild proliferative lesions around the left nostril. A small amount of fecal staining was present at the perineum.

WW 6: The ram appeared slightly thin, had a long pale haircoat and was graded as having fair body and coat condition. A moderate number of *O. megnini* were present in one ear. Discrete depigmented areas were present on the dark mucosa of both nostrils. There was a generalized reduction of body muscling and fat deposits.

Gross necropsy

WW 1: Dependent areas of both anterior, middle and anterior caudal lung lobes were collapsed, plum coloured, firm and sharply demarcated from normal tissue. The affected lung had a cobblestone pattern of pale areas with a redder background. There were small areas of suppuration in a distal portion of one lung lobe. Airways were surrounded by shiny white cuffs and contained a mucoid exudate. Fibrous adhesions fixed most of these areas to the parietal pleura and the pericardium.

Small lungworm nodules were present in the most dorsal area of the caudal lobes and singly in two other lobes. Retropharyngeal, bronchial and mediastinal lymph nodes were twice normal size.

The adrenal glands were twice normal size and the thymus was extremely small. The right kidney contained a firm, depressed, demarcated area that extended deep into the cortex.

The bile duct was moderately thickened and dilated and contained mature *W. tetoni*. The abomasal wall was moderately thickened by multiple pale nodules. Numerous *Trichuris* spp. were present in the cecum. The feces were soft and pasty.

WW 2: Small discrete lungworm nodules were present primarily in the dorsal caudal lung lobes. One small area showed fusion of nodules and pleural thickening.

There were moderate numbers of *W. tetoni* in the bile duct. *Marshallagia* spp. were present in large numbers in the abomasum.

WW 3: The lungs were similar to those of WW 1 except that the consolidation involved a larger proportion of the lung and there was a less abrupt demarcation from normal tissue. Very few lungworm nodules were present and these were restricted to the dorsal caudal lobes.

The adrenal glands were 4-5 times normal size and the thymus was barely identifiable. The joints under the decubitus ulcers contained increased amounts of thickened joint fluid and the synovia were hyperemic. There were fibrinous and fibrous tags over peritoneal surfaces with an increased volume of serous fluid in the abdomen. The abomasal mucosa was moderately to severely thickened by nodules and *Marshallagia* spp. were in moderate numbers. The feces were soft with a foul odor.

WW 4: A small amount of omentum was adherent to the peritoneum and subcutaneous tissue in the middle of the right flank. There were corresponding fibrotic lesions of the abdominal musculature and skin.

There were irregular areas of deep purple, firm, shrunken parenchyma in the dependent portions of all lung lobes. The right lobes were more extensively involved and the right cranial lobe was adherent to the parietal pleura. Small lungworm nodules were scattered over the dorsal caudal lobes.

All visceral and retropharyngeal lymph nodes were enlarged from 2 to 5 times normal size. The spleen was diffusely enlarged to 3 times normal size with prominent, fine, white parenchymal nodules. There was a 2 cm, firm, round, white swelling at the apex of the left ventricle. The renal cortex contained white linear streaks. There was moderate nodular thickening of the abomasal mucosa. The adrenal glands appeared slightly enlarged.

WW 5: There were scattered small lungworm nodules in most lung lobes. Fibrous pleural adhesions were attached to the distal portions of most lobes. A central area of the left cranial lobe was shrunken, red and firm. The bronchial and mediastinal lymph nodes were enlarged.

An area of myocardium at the apex of the heart was pale. There were multiple pale streaks in the renal cortex which were depressed from the surface. Splenic lymphoid follicles were prominent. An encysted larval tapeworm was located adjacent to the duodenum and liver. The abomasum contained a trichobezoar and the mucosa was thickened and corrugated. The adrenal glands were enlarged slightly.

WW 6: The dorsal caudal lobes had small areas of coalescing nodules with pleural thickening. Adult *P. rushi* were present within medium-sized airways. There was a moderate number of *W. tetoni* within a slightly dilated bile duct. A few *Marshallagia* spp. were found in the abomasum.

EWIN RIDGE

Clinical evaluation and condition

ER 1: This lamb was in good physical and haircoat condition with no abnormalities on gross examination. Body fat deposits were moderately reduced but muscling appeared to be maintained.

ER 2: The rump of this ewe was slightly angular but she appeared in good body condition. The haircoat was in good condition. Body fat deposits were moderately reduced in all but the perirenal location. She was the dam of ER 1.

ER 3: The ewe was in good body and haircoat condition and only a slight decrease of body fat deposits was seen.

ER 4: This yearling ram was of small size, but was in good physical condition. The haircoat was pale in colour but in good condition. Body fat deposits were only slightly reduced.

ER 5: This large ewe was in good physical condition with good haircoat. There was little reduction in body fat deposits.

ER 6: The ewe was large and in good physical and haircoat condition. Little change in body fat deposits was noted.

Gross necropsy

ER 1: Single or small fused lungworm nodules were present only in small areas of the dorsal caudal lung lobes of this lamb. Portions of both lungs were severely damaged from the track of the bullet and were not evaluated.

The abomasal mucosa was moderately nodular. The right ovary was absent and approximately one third of the right uterine horn was present only as a ligamentous structure.

ER 2: A few *P. rushi* adults were found within airways of the caudal lobes of the lung. Fused lungworm nodules covered by thickened contracted pleura were in the distal caudal lobes. Larger discrete nodules were more proximally located with a few small nodules over the dorsal aspect of more cranial lobes. The abomasal mucosa was only slightly nodular.

ER 3: There was a healed wound on the neck over the left prescapular lymph node of this ewe. The lymph node below was enlarged and contained a yellow-white caseous exudate. A few discrete lungworm nodules were present in the caudal lobes only.

ER 4: Lungworm nodules in the young ram were restricted to the distal aspect of the caudal lobes and were fused. The overlying pleura was thickened. Nodular lesions of the abomasal mucosa were prominent.

ER 5: The ewe had linear contracted areas several centimetres from the apex of both middle lung lobes. These areas were firm and red. The pleura of the dorsal caudal lobes was thickened and slightly reddened. It covered diffuse, confluent lungworm lesions. Mild adhesions were present between the left distal caudal lobe and the diaphragm.

ER 6: The left middle lung lobe of the last ewe had an area partially contracted, red and firm. Several discrete lungworm nodules were present over the dorsal middle and caudal lung lobes. The dorsal caudal lobes were covered with very thickened pleura and the right distal aspect was markedly contracted.

Copies of Wildlife Bulletins can be obtained, depending on supply, from the Wildlife Branch, Ministry of Environment, Parliament Buildings, Victoria, B.C. V8V 1X5. Titles of Bulletins 1 to 21 are also available.

No. B-22 Landsat classification for wildlife habitat management and research planning: problem analysis. K.L. Sadoway. December 1980. 36pp. (Also printed as IWIFR-6).

No. B-23 Landsat classification: evaluation of image analysis methodologies for wildlife habitat management and research planning: working plan. K.L. Sadoway. May 1980. 29pp. (Also printed as IWIFR-7).

No. B-24 Landsat classification: evaluation of image analysis methodologies for wildlife habitat management and research planning: final report. K.L. Sadoway, ed. July 1983. 177pp. (Also printed as IWIFR-8).

No. B-25 A bibliography of the wolverine *Gulo gulo*. V. Banci. June 1982. 53pp. (Also printed as IWIFR-9).

No. B-26 Problem analysis: grizzly bears and coastal development, with particular reference to intensive forestry. W.R. Archibald. September 1982. 24pp.

No. B-27 The wolverine in British Columbia: distribution, methods of determining age and status of *Gulo gulo vancouverensis*. V.A. Banci. June 1982. 90pp. (Also printed as IWIFR-15).

No. B-28 Vancouver Island Roosevelt elk/intensive forestry interactions: problem analysis. D. Janz, K. Brunt and J. Youds. December 1980. 36pp. (Also printed as IWIFR-11).

No. B-29 Vancouver Island Roosevelt elk/intensive forestry interactions: working plan 1981 - 1985. D. Janz, K. Brunt and J. Youds. December 1980. 60pp. (Also printed as IWIFR-12).

No. B-30 Intensive forestry effects on Vancouver Island deer and elk habitats. J.B. Nyberg. 1985. (Also printed as IWIFR-16).

No. B-31 Trees and snow: the deposition of snow on the ground. A review and quantitative synthesis. F.L. Bunnell, S. McNay and C.C. Shank. 1985. (Also printed as IWIFR-17).

No. B-32 Vancouver Island Roosevelt elk/intensive forestry interactions. October 1982 - September 1983. K. Brunt, J. Youds and D. Becker. September 1984. 67pp. (Also printed as IWIFR-13).

No. B-33 Reliability of motion-sensitiveness and radio-collars for estimating activity of blacktail deer. M.P. Gillingham and F.L. Bunnell. 1985. (IWIFR-14; printed in Journal of Wildlife Management. 1985. 49(4): 951-958).

No. B-34 Deer movement and habitat use during winter: working plan. J.B. Nyberg, D. Doyle, L. Peterson. 1985. (Also printed as IWIFR-18).

No. B-35 Forest crowns, snow interception and management of black-tailed deer winter habitat. R.S. McNay. 1985. (Also printed as IWIFR-19).

No. B-36 Comparison of methods for estimating forest overstory cover. D.J. Vales and F.L. Bunnell. 1985. (Also printed as IWIFR-20).

No. B-37 Vancouver Island Roosevelt elk/intensive forestry interactions: progress report 1981-1984. J. Youds, K. Brunt and D. Becker. 1985. (Also printed as IWIFR-21).

No. B-38 Interactions between black-tailed deer and intensive forest management: problem analysis. R.S. McNay and R. Davies. 1985. (Also printed as IWIFR-22).

No. B-39 The Vancouver Island marmot: status and management plan. W.T. Munro, D.W. Janz, V. Heinsalu and G.W. Smith. June 1985. 28pp.

No. B-40 Effects of intensive forest management on amphibians and reptiles of Vancouver Island: problem analysis. K.L. Sadoway. 1985. (Also printed as IWIFR-23).

No. B-41 Effects of intensive forest management on non-ungulate mammals of Vancouver Island: problem analysis. K.L. Sadoway. 1985. (Also printed as IWIFR-24).

No. B-42 Effects of intensive forest management on breeding birds of Vancouver Island: problem analysis. K.L. Sadoway. 1985. (Also printed as IWIFR-25).

No. B-43 Enhancing the establishment and growth of arboreal forage lichens in intensively managed forests: problem analysis. S.K. Stevenson. 1985. (Also printed as IWIFR-26).

No. B-44 Managing young forests as black-tailed deer winter range. J.B. Nyberg. 1986. (Also printed as IWIFR-27).

No. B-45 A rationale for wolf control in the management of the predator-ungulate system. D. Janz and I. Hatter. March 1986. 35pp.

Continued on back cover

Continued from inside back cover

No. B-46 Thermoregulation and thermal cover of seed and elk on Vancouver Island: problem analysis. F.L. Bunnell, K.L. Parker, L.L. Kremsater and S.W. Hovey. 1986. (Also printed as IWIFR-28).

No. B-47 The effects of heat, cold and rain on coastal black-tailed deer. K.L. Parker. 1987. (Also printed as IWIFR-39). (In prep.).

No. B-48 Raising black-tailed deer at natural growth rates. K.L. Parker and B. Wong. 1986. (IWIFR-30; Printed in Canadian Journal of Zoology).

No. B-49 Estrus in black-tailed deer. K.L. Parker and M.P. Gillingham. 1986. (IWIFR-31; in press, to be printed in the Journal of Mammology).

No. B-50 Functional relationships between salal understory and forest overstory. D.J. Vales. 1986. (Also printed as IWIFR-32).

No. B-51 Vancouver Island Roosevelt elk/intensive forestry interaction - phase I (1981-1986). Job completion Report. K. Brunt, D. Becker and J. Youds. 1987. (Also printed as IWIFR-33)(In. prep.).

No. B-52 Wolf management in British Columbia: the public controversy. R. Hoffos. May 1987. 83pp.

No. B-53 Habitat selection by black-tailed deer on Vancouver Island: Job Completion Report. R.S. McNay and D.D. Doyle. 1987. (Also printed as IWIFR-34).

No. B-54 Shrub burial by snow deposition in immature coastal forests. F.W. Hovey. 1987. (Also printed as IWIFR-35).

No. B-55 Deer use of old-growth and immature forests following snowfalls on southern Vancouver Island. J. B. Nyberg, L. Peterson, L.A. Stordeur and R.S. McNay. 1987. (Also printed as IWIFR-36)(In prep.).

No. B-56 Understory responses to thinning and fertilization. J.B. Nyberg, L. Peterson, and L.A. Stordeur. (Also printed as IWIFR-37)(In prep.).

No. B-57 Movements amd habitats of caribou in the mountains of southern British Columbia. K. Simpson and G.P Woods. May 1987. 41pp.

No. B-58 Evaluation of health status of Rocky Mountain sheep (*Ovis canadensis canadensis*) in southeastern British Columbia. H. M. Schwantje. April 1988. 64pp.